Automatic Ring Sizer and Availability Checker

by

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A Design Report Submitted to the School of Electrical Engineering, Electronics and Communications Engineering, and Computer Engineering in Partial Fulfillment of the Requirements for the Degree

Bachelor of Science in Computer Engineering

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Approval Sheet

Mapúa Institute of Technology
School of EE-ECE-CoE

This is to certify that we have supervised the preparation of and read the design report prepared by **Marie Chona O. Andres, Sheena Roi C. Guegue, Ervin John G. Pineda, Jeffrey D. Simbulan, and Mark Marion P. Suresca** entitled **Automatic Ring Sizer and Availability Checker** and that the said report has been submitted for final examination by the Oral Examination Committee.

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As member of the Oral Examination Committee, we certify that we have examined this design report, presented before the committee on **July 10, 2009,** and hereby recommended that it be accepted as fulfillment of the design requirement for the degree in **Bachelor of Science in Computer Engineering.**

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ABSTRACT

Automatic Ring Sizer and Availability Checker is a device intended to develop a system that measures the size of a finger and verifies the availability of the customer's preferred ring. A fiber-optic proximity sensor is used to detect the presence of the finger. Once identified, the stepper motor counts the number of rotation it has made and sends it to the microcontroller to determine the size of the finger. Since the fiber optic proximity sensor is a non-contact sensor, offset value is added to the original size. The microcontroller will send back the data to the computer then accessed to a software database. After the development of the design, the testing made verifies the accuracy of the design which is almost the same with the existing manual ring sizer available in the market.

Keywords: Fiber Optic Proximity Sensor, Stepper Motor, Microcontroller, Offset Value, Software Database

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Chapter 1

DESIGN BACKGROUND AND INTRODUCTION

Design Setting

People from all cultures are fond of wearing jewelries for personal adornment. One kind of jewelry is the ring which is a circular band usually used to decorate the fingers.

Different techniques are used in measuring the size of the finger. During ancient times measuring the size of the finger made use of a string, ruler, pen and paper. The technique was to wrap a piece of string or strip of paper around the finger, making sure that it was neither too tight to bind and that it could slide over the knuckle of one's finger without difficulty, nor so loose that it would slip over the knuckle almost by itself, thus easily fell off. Finding this comfort zone, marked the point where the two ends meet. Lastly, lay the string or strip of paper against a ruler to determine the circumference and record it.

Today, jewelry shops used improvise ring sizer or ring stick to measure the finger size. The ring sizers are marked with different ring sizes and the customer determines which one fits well.

Statement of the Problem

Today, to determine the finger size jewelry owners make use of different manual measuring devices like using strings and rulers or improvised ring sizers and ring sticks used by most jewelry shops. Ring sizers are circular bands that have different diameter sizes. Many customers had found that trying on wedding bands in different diameter sizes was the easiest way to determine the exact ring size, but the method was tedious and would consume much time. Given this premise, the proponents desired to improve the manual operation in determining the finger size and choosing the clients preferred rings without hassle.

The Objective of the Design

The primary objective of this design is to automate the existing manual technique in measuring the sizes of the fingers. Listed below are few things that the proponents want to attain on the design to make it more efficient like:

1. To be able to utilize a sensor that will measure the size of the finger.
2. To create a database that will store the customer's profile and finger sizes which can be used for future references.
3. To interface the design to the computer with the use of serial communication.

The Significance of the Design

The design will be beneficial to the jewelry shop owners, sales staffs, and customers. With the Automatic Ring Sizer and Availability Checker, the customers will be given easier and convenient way to measure their finger sizes. This may increase customer service satisfaction; hence the sales staffs could accommodate more customers and increase the profits of the jewelry shop owners at the shortest time compared to the manual process.

The Conceptual Framework

Figure 1.1 shows the conceptual framework of the design. The Input-Process-Output Model illustrates the primary system of the Automatic Ring Sizer and Availability Checker.

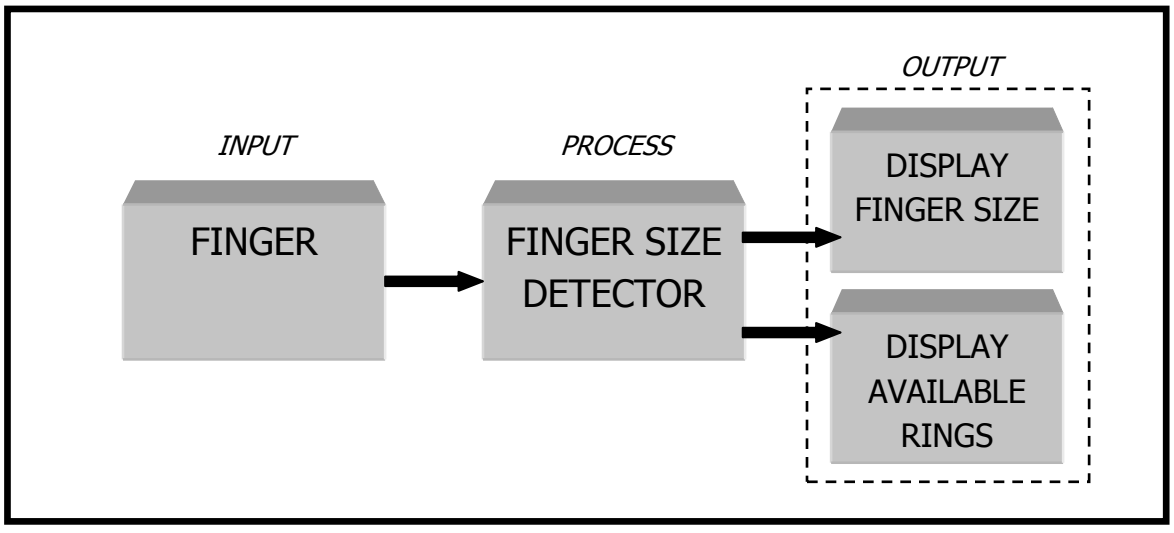

Figure 1.1: Conceptual Framework

Automatic ring sizer and availability checker is an automatic device used to determine the size of the finger of the customer. The design will begin its operation when the finger is positioned to the ring sizer hardware properly. The finger serves as the input data of the device. The prototype is serially interfaced to a computer terminal using a DB-9 Connector. The design uses a microcontroller which controls the movement of the Unipolar Stepper Motor. The stepper motor determines the size of the finger by counting the number of rotation it has made. The stepper motor stops when the fiber optic proximity sensor reflected beam is interrupted by an opaque object. The enter button on the computer is pressed to complete the process. Since the fiber optic proximity sensor is a non-contact sensor, offset value is added to the original size. The output data, finger size is directly send to the customer's database and stored. Upon storing the size of the customer's finger, the customer can choose different rings from the database. It has a database for different ring images and sizes and customer's profile.

The Scope and Delimitation

The proponents have set the scope and delimitation of the design as follows:

Scope:

1. The prototype performs an operation that automatically measures the size of the finger.

2. The prototype can measure one finger at a time.
3. The prototype makes use of stepper motor and fiber optic proximity sensor. The stepper motor stops when an object interrupted the reflected beam of the fiber optic proximity sensor.
4. The prototype utilizes serial port communication using DB-9 connector cable that can be used on desktop computer.
5. The prototype adds a constant offset value to the original measure of the finger because the fiber optic proximity sensor used is a non-contact sensor.
6. The design software can add, modify, and delete information of the customer.
7. The design software can modify and delete existing ring record.
8. The design measurement ranges from 10mm (minimum) to 25mm (maximum).
9. The final measure of the finger which is in millimeter is converted to the USA Standard Ring Size using the International Ring Size Conversion Chart.

Delimitation:

1. The fiber optic proximity sensor used is a non-contact type of sensor.
2. The prototype measures the diameter of the finger.
3. There is no level of hierarchy for account logging.

4. The program does not utilize a module for adding entry for new ring information.
5. The design software does not generate sale transactions.
6. Fingers should not be measured when the temperature is cold; this is when fingers are their smallest.

Definition of Terms

1. **Alternating Current.** Electric current that reverses direction periodically, usually many times per second. *(Beaty H., Standard Handbook for Electrical Engineers, 15th Edition, 2007).*
2. **Capacitor.** A device which consists essentially of two conductors (such as parallel metal plates) insulated from each other by a dielectric and which introduces capacitance into a circuit, stores electrical energy, blocks the flow of direct current, and permits the flow of alternating current to a degree dependent on the capacitor's capacitance and the current frequency. *(Terrell Croft, American Electricians' Handbook, 15th Edition, 1992).*
3. **Compiler.** An application program in development software packages that controls the design flow process and translates source code into object code in a format that can be logically tested or downloaded to a

target device. *(Floyd, L. T., Digital Fundamentals with PLD Programming. New Jersey: Pearson Prentice Hall, 2006).*

4. **Database.** A collection of information organized in such a way that a computer program can quickly select desired pieces of data. One can think of a database as an electronic filing system. *(Takahashi, The Manga Guide to Databases, 2006).*
5. **DB 9 Connector.** A serial port connector which includes nine important signal pin connectors. *(Thompson et al., PC Hardware in a Nutshell, 3rd edition, 2003).*
6. **Debugging.** Error made in writing a program by which error the users are not aware. Errors can be quite simple such as typing errors and quite complex such as incorrect use of program language. Assembler will find most of these errors and report them to '.LST' file. Other errors will need to be searched for by trying it out and watching how device functions. *(Nebojsa Matic, PIC microcontrollers, 2005).*
7. **Diode.** It consists of a silicon wafer containing nearly equal p-type and n-type impurities, with additional p-type impurities diffused from one side and additional n-type impurities from the other side. This leaves a lightly doped intrinsic layer in the middle to act as a dielectric barrier between the n-type and p-type regions which is also known as power diode. *(Christiansen, Standard Handbook of Electronic Engineering, 5th Edition, 2005).*

8. **Etching**. It is the process of using strong acid or mordant to cut into the unprotected parts of a metal surface to create a design in intaglio in the metal. *(Abrams, et al., Computer Hardware and Software, Illustrated Edition, Addison-Wesley, 1973).*
9. **Fiber Optic Proximity Sensor.** A proximity sensor is a device used to detect the presence of an object. Fiber optic proximity sensors are devices which use a light beam transmitted from a light source by way of a bundle of light conducting optical fibers from a light source to a target. *(Brian S. Elliott, Electromechanical Devices and Components Illustrated Sourcebook, 2007).*
10. **Finger.** It is a digit of the hand, including the thumb. *(Hanson, Contemporary Ergonomics, 2001).*
11. **Graphical User Interface (GUI).** A method of interacting with the computer that allows any image to be displayed on screen (graphics based). Although a keyboard is used to enter text, the primary way to command the computer is with a mouse or touchpad pointing device. *(Takahashi, The Manga Guide to Databases, 2006).*
12. **Hardware.** Machinery and equipment (CPUs, disk and tape drives, modems, keyboards, printers, scanners, cables, etc.). In operation, a computer is both hardware and software. One is useless without the other. The hardware design specifies the commands it can follow, and the

software instructions tell what to do. *(Takahashi, The Manga Guide to Databases, 2006).*

13. **HEX File.** This is a file made by assembler translator when transcoding a source file and has a form "understood" by microcontrollers. A continuation of the file is usually File_name.HEX where the name HEX file comes from. *(Nebojsa Matic, PIC microcontrollers, 2005).*
14. **Input/Output Pin.** External microcontroller's connector pin which can be configured as input or output. In most cases I/O pin enables a microcontroller to communicate, control or read information. *(Nebojsa Matic, PIC microcontrollers, 2005).*
15. **Knuckle. T**he rounded prominence formed by the ends of the two adjacent bones at a joint —used especially of those at the joints of the fingers. *(Hanson, Contemporary Ergonomics, 2001).*
16. **Metal Oxide Semiconductor Field-Effect Transistor.** A field-effect transistor having a gate that is insulated from the semiconductor substrate by a thin layer of silicon dioxide. Abbreviated MOSFET; MOST; MOS transistor formerly known as insulated-gate field-effect transistor (IGFET). *(Harper, Electronic Materials and Processes Handbook, 3rd Edition, 2006).*
17. **Microcontroller.** A microcomputer, microprocessor, or other equipment used for precise process control in data handling, communication, and

manufacturing. *(Donald Christiansen, Standard Handbook of Electronic Engineering, 5th Edition, 2005).*

18. **Offset.** The distance from a starting point, either the start of a file or the start of a memory address. Its value is added to a base value to derive the actual value. *(Hanson, Contemporary Ergonomics, 2001).*
19. **PIC16F84A Microcontroller.** It belongs to a class of 8-bit microcontrollers of Reduced Instruction Set Computers architecture. *(Nebojsa Matic, PIC microcontrollers, 2005).*
20. **Plug.** The half o f a connector that is movable and is generally attached to a cable or removable sub-assembly inserted in a jack, outlet, receptacle, or socket. *(Terrell Croft, American Electricians' Handbook, 15th Edition, 1992).*
21. **Power Switch.** An electric switch which energizes or de-energizes an electric load, ranges from ordinary wall switches to load-break switches, and disconnecting switches in power systems operating at voltages of hundreds of thousands of volts. *(Basso, Switch-Mode Power Supplies: SPICE Simulations and Practical Designs, 2008).*
22. **Printed Circuit Board.** A flat board whose front contains slots for integrated circuit chips and connections for a variety of electronic components, and whose back is printed with electrically conductive pathways between the components. It is also known as circuit board. *(Coombs, Printed Circuits Handbook, 5th Edition, 2001).*

23. **Program.** A collection of instructions that tells the computer what to do. A program is generically known as "software" and the programs' users work with such as word processors and spreadsheets are called "applications" or "application programs." Thus, the terms software, application, program, and instruction are synonymous in the sense that these all tell the computer what to do. *(Takahashi, The Manga Guide to Databases, 2006).*
24. **Proximity Sensor.** Any device that measures short distances within a robotic system and also known as noncontact sensor. *(Elliott, Electromechanical Devices and Components Illustrated Sourcebook, 2007).*
25. **Resistor.** A device designed to have a definite amount of resistance used in circuits to limit current flow or to provide a voltage drop. *(Christiansen, Standard Handbook of Electronic Engineering, 5th Edition, 2005).*
26. **Ring.** A band usually made of precious metal and often engraved or mounted with gemstones worn as an ornament especially around a finger. *(Hanson, Contemporary Ergonomics, 2001).*
27. **Ring Sizer.** A measuring device for the fingers which is a circular band with different sizes. *(Celis, Personal Interview, 2009).*

28. **Ring Stick.** A measuring device for the fingers which is a cylindrical cone that has markings on the edge denoting the size of the ring. *(Celis, Personal Interview, 2009).*
29. **RS-232 (Recommended Standard-232).** A TIA/EIA standard for serial transmission between computers and peripheral devices (modem, mouse, etc.) Using a 25-pin DB-25 or 9-pin DB-9 connector, its normal cable limitation of 50 feet can be extended to several hundred feet with high-quality cable. *(Elliott, Electromechanical Devices and Components Illustrated Sourcebook, 2007).*
30. **Serial Interface.** A data channel that transfers digital data in a serial fashion: one bit after the other over one wire or fiber. The serial port on a PC is a serial interface that is typically used to attach modems and data acquisition terminals. On earlier PCs, mice are also used as the serial port. USB and FireWire (IEEE 1394) are high-speed serial interfaces that have superseded the serial port. Serial interfaces may have multiple lines, but only one line is used for data. *(Elliott, Electromechanical Devices and Components Illustrated Sourcebook, 2007).*
31. **Simulator.** Software package for PC which simulates the internal function of microcontroller. It is ideal for checking software routines and all the parts of the code which does not have over demanding connections with an outside world. Options are installed to watch the

code, movement around the program back and forth, step by step, and debugging. *(Nebojsa Matic, PIC microcontrollers, 2005).*

32. **Software.** This deals with the details of an ever-changing business and must process transactions in a logical fashion. Languages are used to program the software. The "logic and language" involved in analysis and programming is generally far more complicated than specifying a storage and transmission requirement. *(Takahashi, The Manga Guide to Databases, 2006).*
33. **Stepper Motor.** A motor that rotates in short and essentially uniform angular movements rather than continuously, typical steps are 30, 45, and 90°; the angular steps are obtained electromagnetically rather than by the ratchet and pawl mechanisms of stepping relays. *(Elliott, Electromechanical Devices and Components Illustrated Sourcebook, 2007).*
34. **Switch Mode Power Supply.** It is an electronic power supply unit that incorporates a switching regulator. The AC mains insert a 120-V_{RMS} AC signal into the SMPS input, where high amplitude transients attempting to enter the supply and cause damage will be shortened to ground through MOV (metal oxide varistor), thus imparting limited protection from any voltage surges or lightning strikes. *(Sayre, Complete Wireless Design, 2nd Edition, 2008).*

35. **TTL (Transistor-Transistor Logic).** A type of fixed-function digital circuit technology that uses bipolar junction transistors. *(Floyd, Digital Fundamentals with PLD Programming. New Jersey: Pearson Prentice Hall, 2006).*
36. **Universal Asynchronous Receiver Transmitter (UART).** The electronic circuit that makes up the serial port. Also known as "universal serial asynchronous receiver transmitter" (USART), it converts parallel bytes from the CPU into serial bits for transmission and vice-versa. It generates and strips the start and stop bits appended to each character. Note that in the following paragraphs, dashes have been added after the 16 for readability. Older 8250 and 16-450 UARTs are not fast enough for today's modems. A 16-550 is required for transmission up to 115,200 bps (115 Kbps). *(Elliott, Electromechanical Devices and Components Illustrated Sourcebook, 2007).*
37. **Vernier Caliper.** An instrument used for in determining accurate linear measurements. *(Elliott, Electromechanical Devices and Components Illustrated Sourcebook, 2007).*
38. **Voltage Regulator.** A device that maintains the terminal voltage of a generator or other voltage source within required limits despite variations in input voltage or load. *(Beaty, Standard Handbook for Electrical Engineers, 15th Edition, 2007).*

Chapter 2

REVIEW OF RELATED LITERATURE AND RELATED STUDIES

The concept of the design comes from existing ideas and related studies that are done in the past. The design prototype is unique and one of a kind because the resources used happened to be limited. Books, magazines, internet, and interviews from jewelry shop sales staff became the primary source of information regarding different methods in measuring finger sizes. It provides knowledge on how to measure ring sizes manually.

Different Manual Methods/Devices Used in Measuring Ring Size

According to the concepts from the book, The Budget Wedding Sourcebook by Madeline Barillo it stated that choosing wedding and engagement rings were a momentous decision not only on the style of the ring but also in terms of its sizes. The ring should fit properly and comfortably over the knuckle and hug the base of the finger without sliding around too easily. So, when buying a ring it is important to have the right size. A person would not want to have a ring that didn't fit properly. It will be very disappointing if a ring was too big or too small that is why measuring ring size is important in buying any type of ring.

Hence, the proponents have decided to create an automatic ring sizer and availability checker which is an alternative way of measuring the size of the fingers in automatic mode. These concepts were used as significant information implementing the design prototype since it involved measuring ring sizes.

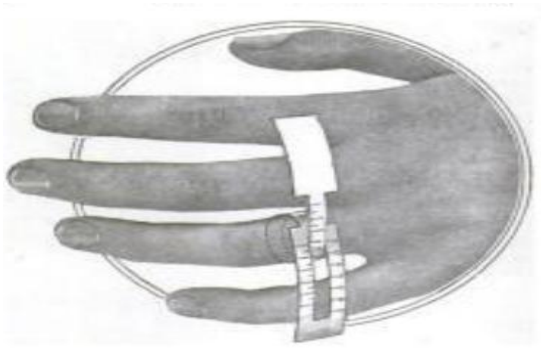

Figure 2.1: Finger Measurer

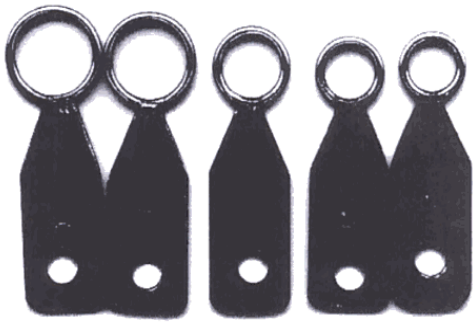

Figure 2.2: Example Of The Sizers Produced In A School Design

An article taken from the magazine Applied science entitled "Science Applied to Wedding Rings" by Julius Dinhofer of New York (2005) invented a finger measurer shown in Figure 2.1. This device is a strip of paper film with a slit in one end through which the other end may pass. It is designed to measure the size of the finger by slipping the end of the paper through the opening and adjusting it to the finger. And it has a scale printed along on the edge of the paper which tells the size of the finger.

Another technique in measuring the size of the finger is to use a ring sizer as shown on Figure 2.2. According to a book, Contemporary Ergonomics, by

Margaret Hanson, 2001, Ergonomics Society Conference, a ring sizer is a measuring device for fingers which is composed of circular bands that have different sizes. The designer recorded the smallest size through which the finger would freely pass without the application of force.

The proponents studied Hanson's work. It measured the diameter of the finger. Also, the movements of the unipolar stepper motor corresponded to a single step. For every one revolution of the motor created was equivalent to 1 millimeter in size. The generated steps to complete one cycle of the motor were 200 steps having 1.8º movements.

Figure 2.3: Ring Sizer

Figure 2.4: Ring Stick

From the team's interview with Ms. Jhonasel R. Celis, Sales Staff of Suarez Wedding Rings Shop, where the shop used two kinds of measuring devices, namely: a ring sizer and a ring stick. Figures 2.3 and 2.4 are examples of ring sizers and ring stick that are presently used in most jewelry shops and designed for measuring ring sizes. Celis discussed on how to measure the size of the fingers using the said devices. First, the ring stick (graduated cone) was used when an available ring was present. Ring stick had markings on the cone denoting the ring sizes. The ring was put on the cone and its size was read where it fitted securely on the cone. Otherwise, the ring sizers were used. Ring sizers were usually group of rings with different sizes. As shown in Figure 2.3, there were two kinds of ring sizer. A ring sizer that was 1mm thick for standard rings and a ring sizer that was 3mm thick for engagement/wedding ring.

The discussed procedures were used by the proponents in comparing the results of the automatic ring sizer from the manual process to determine the measurement of the finger. The standard ring size and ring stick that was purchased in the market was used.

Table 2.1 is an excerpt from the International Ring Size Conversion Chart. Different countries have different ring-size systems. The American Standard Measurement is the common ring standard used in measuring the size of the finger. It shows the inside circumference or diameter (in inches and millimeter) size of the ring and the corresponding ring sizes by other countries.

The table was used for the Ring Calibration and Finger Diameter Measurement System 1.0. The obtained measurement of the design prototype (in millimeter) was converted using the USA size of the International Ring Size Conversion Chart.

Inside Circumference (inches)	Inside Circumference (mm)	Inside Diameter (mm)	U.S.A. size	Japanese size	British size	German size	Swiss size
1 12/16	46	14.68	**3¾**	5	G½	14	6 1/2
1 14/16	46	14.88	**4**	6	H	14 ½	--
1 13/16	47	15.09	**4¼**	7	H½	15	7 3/4
1 14/16	48	15.27	**4 ½**	8	I - ½	15 1/4	--
1 15/16	49	15.70	**5**	9	J ½	15 3/4	--
2	51	16.10	**5 ½**	11	L	16	11 3/4
2 1/16	52	16.51	**6**	12	M	16 1/2	12 3/4
2 2/16	53	16.92	**6 ½**	13	N	17	14
2 3/16	55	17.35	**7**	14	O	17 1/4	15 1/4
2 4/16	56	17.75	**7 ½**	15	P	17 3/4	16 1/2
2 5/16	57	18.19	**8**	16	Q	18	17 3/4
2 6/16	58	18.53	**8 ½**	17	Q ½	18 1/2	--
2 7/16	59	18.89	**9**	18	R ½	19	--
2 8/16	61	19.41	**9 ½**	19	S ½	19 1/2	--
2 9/16	62	19.84	**10**	20	T ½	20	--
2 10/16	63	20.20	**10 ½**	22	U ½	20 1/4	--
2 11/16	65	20.68	**11**	23	V ½	20 3/4	--
2 12/16	66	21.08	**11 ½**	24	W ½	21	--
2 13/16	68	21.49	**12**	25	Y	21 1/4	27 1/2
2 14/16	69	21.89	**12 ½**	26	Z	21 3/4	28 3/4
2 15/16	70	22.33	**13**	27	--	22	--
3	71	22.61	**13 ½**	**--**	--	--	--
3 1/16	72	23.01	**14**	**--**	Z3	--	--
3 2/16	73	23.42	**14 ½**	**--**	Z4	--	--
3 3/16	74	23.83	**15**	**--**	--	--	--
3 4/16	76	24.23	**15 ½**	**--**	--	--	--
3 5/16	77	24.64	**16**	**--**	--	--	--

Table 2.1: Example Of International Ring Sizes Conversion Chart

Finger Ring Size Adjusting Device and Method

An article entitled "Finger Ring Size Adjusting Device and Method" by Bryan J. Miller, the inventor from United States Patent Online, Patent Number 6003334 2005, stated that the invention relates generally to a finger ring size opening adjustment device for enhancing the retention of a finger ring on the wearer's finger and, more particularly to an adjustment device adapted to the ring shaft in permitting passage of the ring over an enlarged knuckle for fitting a digital portion of the finger.

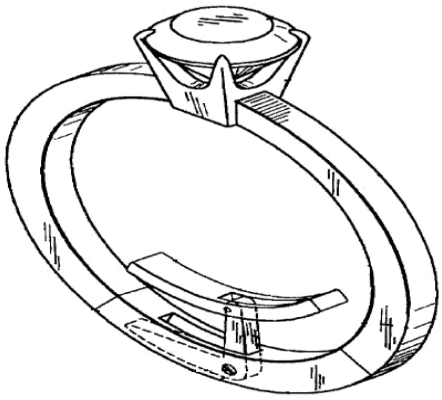

Figure 2.5: Finger Ring Size Adjusting Device

Figure 2.5 is an example of the invention in elevation view, an adjustable ring sizing device. The topics discussed in the article gave the designers an overview on how to automate the finger ring size adjusting device. The device invented comprised of a ring shaft and a cradle which was biased radically

inward from the shaft. The cradle was moveable between a retracted position and an adjusted position for reducing the ring size. The ring wearer, thus had an adjustable ring shaft for easily sliding over an enlarged knuckle or joint, and then to a desired fit on the phalanx portion of the finger.

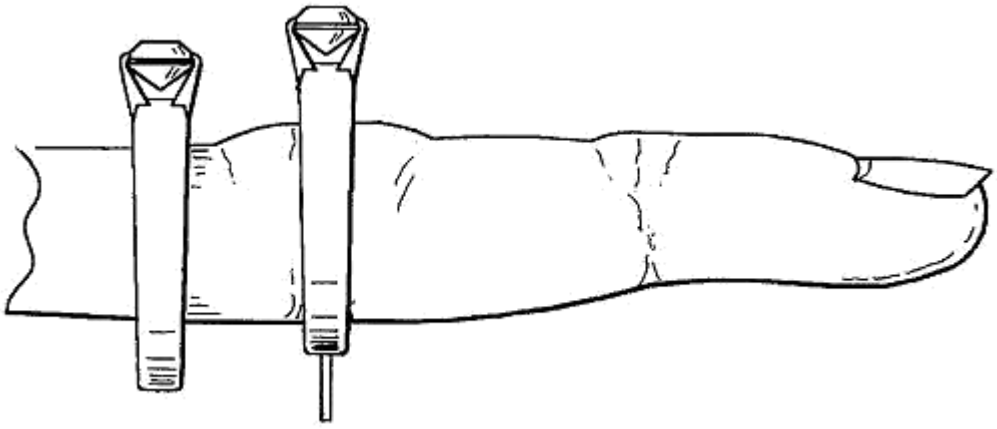

Figure 2.6: Finger Ring Size Adjusting Device In A Finger

Fgure 2.6 shows a partial view of the finger ring size adjusting device on a finger illustrating operation of the invention passing over a knuckle of the finger to a closed position worn on a digital portion of the finger.

Fiber Optic Proximity Sensor

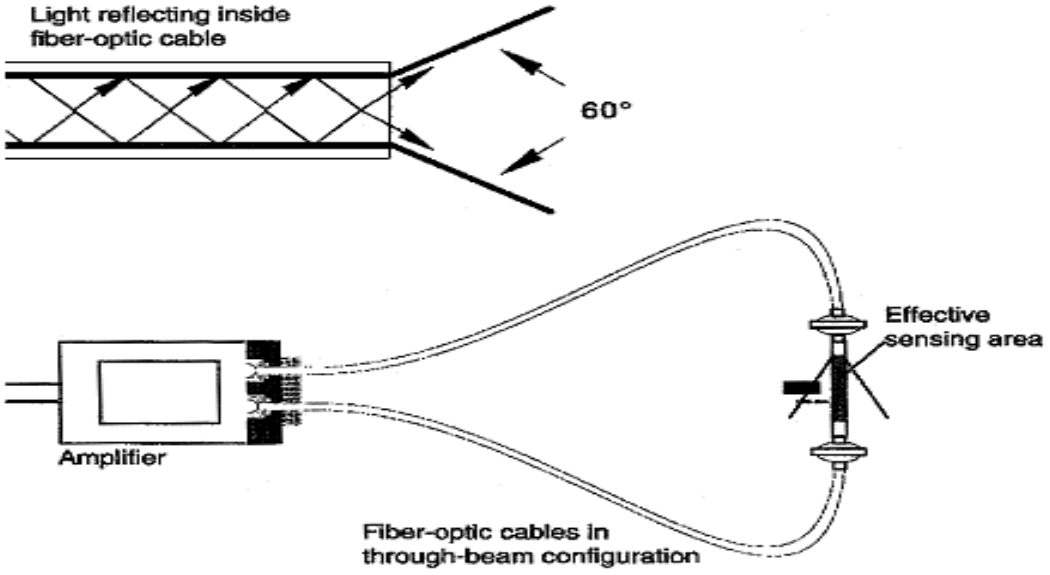

Figure 2.7: In A Fiber-Optic Sensing System

A fiber optic sensor system as shown in Figure 2.7 consisted of a fiber-optic cable connected to a remote sensor, or amplifier. The sensor emitted, received, and converted the light energy into an electrical signal. The cable was the mechanical component that transported the light into and out of areas that were either too space constrained or too hostile back to the sensor.

The measurement of displacement, position, or location was an important concept in the development of this design. Thus, fiber optic proximity sensor was used. Some features of fiber optic proximity sensor provided high precision up to 0.002mm resolution and high temperature up to 170º Celsius operating range.

Foot Size Measurer and Foot Size Availability Checker

Foot Size Measurer and Foot Size Availability Checker was a previous design by Delos Santos et al., July 2006. In this design the materials used in measuring the size of the foot consisted of a microcontroller, stepper motor, and two switches. It was interfaced to the computer using a parallel cable.

The design gave the proponents to come up with the concepts on how to develop another design which measured the size of a finger automatically and showed the available desired ring with the customer's finger size.

Unipolar Stepper Motor

Figure 2.8: Stepper Motor

From the Standard Handbook for Electrical Engineers, 15th edition Beaty 2007, stated it that the primary characteristic of a stepper motor was its ability to rotate a prescribed small angle (step) in response to each control pulse applied to its windings. About 200 pulses per second, the motor rotated in discrete steps in synchrony with the pulses at higher frequencies up to 16,000 pulses per second, the motor skewed without stopping between pulses. Although motors were available for step angles of 90º to 180º, the common step was 1.8º.

Unipolar Stepper Motor as shown in Figure 2.8 was applied in the design because it required controlled movement. It can be used as an advantage in applications where it needed speed, position and synchronization. Since the design needed speed and controlled movement in measuring the size of the finger the stepper motor was used.

Vernier Caliper

Figure 2.9: Vernier Caliper

As stated in the Brittanica's Encyclopedia, vernier caliper Figure 2.9 is an instrument used for in determining accurate linear measurements. As shown, it utilized two graduated scales: a main scale similar to that of a ruler and especially graduated auxiliary scale. The vernier that slides parallel to the main scale and enables readings to be made to a fraction of a division on the main scale. Vernier calipers are widely used in scientific laboratories and in manufacturing for quality control measurements.

The proponents have conceptualized the design into a form of this caliper. Some sort of instrument to help detect the displacements of an object. Inasmuch as it is a caliper, the idea of displacement being used for the measurement of the design came from the vernier concept.

Effect of Temperature in Finger Muscles

As stated in *Encyclopaedia of Occupational Health and Safety* by Jeanne Mager Stellman, International, 2001; "There is a pronounced effect of cold on muscular functions and performance." Coolness of the environment contract muscles and slows down neural processes.

With this in mind, problems may arise in the precision measuring of the device in cold temperature. Measurements may vary when taken from different room temperature but the differences are in fractions of a millimeter.

Chapter 3

DESIGN METHODOLOGY AND PROCEDURES

Design Methodology

Developmental research was used as the design methodology of this research. It is defined as a systematic study of designing, developing and evaluating constructional programs, processes, and products that must meet the criteria of internal consistency and effectiveness (Design & Development Research, Richey & Klein, 2001). It is a process to examine the usefulness and accurateness of automatic ring sizer as to the traditional manual method in determining the size of the finger. To further understand the design concepts, additional information and concepts needed were gathered from books, magazines, and interviews from the jewelry shop salesclerks became the primary source of information regarding different methods in measuring finger sizes. The gathered data provided knowledge on how to automate and implement the design prototype.

Design Procedure

Figure 3.1 shows the flowchart diagram on how the research study was done. The first step was to identify the problem which was how to automate the existing manual process in determining the ring sizes. The next step after identifying the problem is to form possible solutions that could help in the development of the design. Then, relevant and informative data were gathered to support the research study, such as related literature and studies. These related literature and studies are basically organized and synthesized collection of citations taken from other articles and studies. Then followed by collecting information concerning the materials and components to be used which are appropriate and suitable for the design prototype. The development of the design started when all the required materials and components were available.

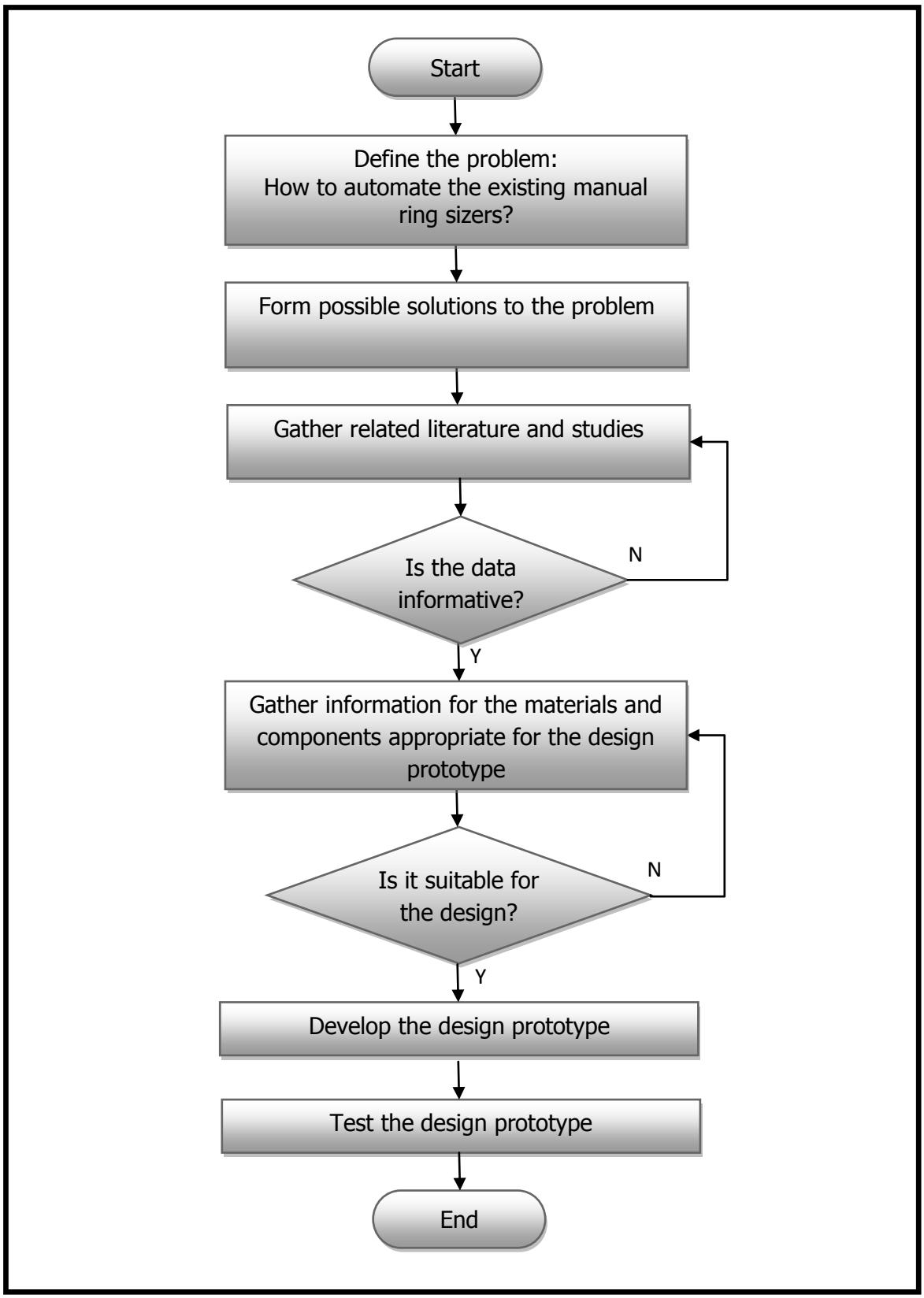

Figure 3.1: Design Procedure

Design Procedure for Actual Design

The development of the design started when all the required materials and components were available. Figure 3.2 shows the block diagram of the actual design procedure. The software and hardware development can be accomplished at the same time.

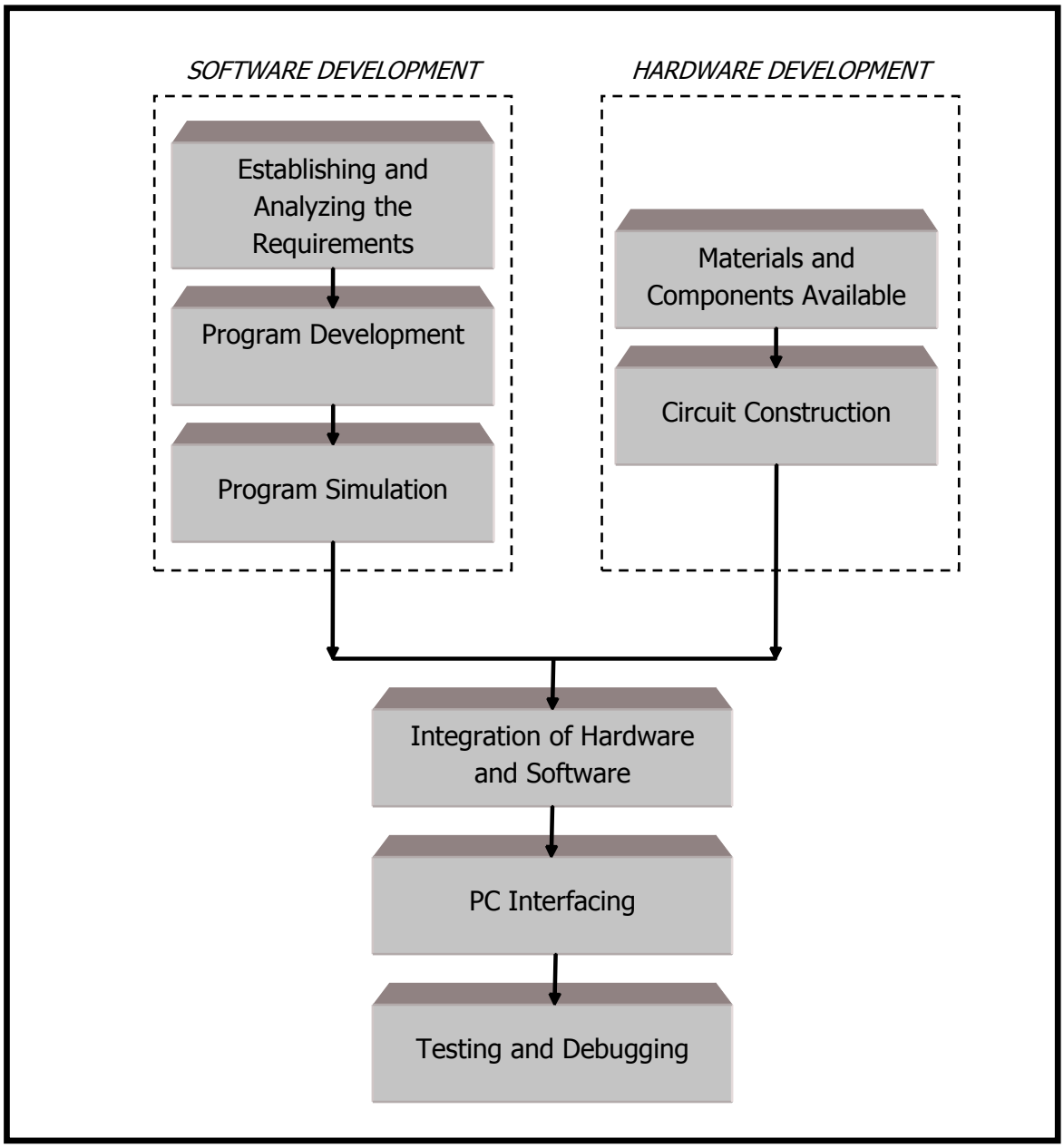

Figure 3.2: Actual Design Procedure

The step by step procedures that the proponents followed in constructing the research design are as follows:

SOFTWARE DEVELOPMENT

1. Establishing and analyzing the requirements
    a. The work began by establishing the requirements needed in the software. This was the most important task in creating software. The proponents discussed all the applicable factors and concepts in development of the software program.
    b. Once the ideal system was engineered or brought about, the proponents analyzed the software requirements for the system. Some functionality may be out of scope on the design functions as cost or as a result of unclear requirements at the start of development. Hence, the overall software's requirements and structures should be clearly stated.
2. Program Development
    a. The design must be translated into a machine-readable form. The procedure that executed this task was the code generation.
    b. Create the program, successfully compile it and then generate the HEX file.
    c. MPASM v03.30-Microchip application was used to generate the HEX file of the program made.

d. The programming tool MicroC Electronica was used for coding and was developed using the C Language. The generated program will be shown in the latter part of this chapter.
e. Then, burn the program using a compatible Microchip PIC kit burner.

3. Program Simulation
    a. Using the MicroC Electronica simulated the code generated and checked if all functions were working properly and if there were no errors.

HARDWARE DEVELOPMENT

1. Materials and components available.
    a. The design started after gathering all the material components and information needed for the creation of the design prototype.
2. Circuit Construction.
    a. Using the PCB Wizard software, develop the PCB layout of the automatic ring sizer. Print the PCB layout in acetate.
    b. Cut the printed circuit board.
    c. Position the printed acetate with PCB layout on top of the printed circuit board. Expose it to UV light for about 30 seconds up to 1 minute.

d. Dissolve right amount of developer in water. Place the exposed printed circuit board into the solution and wait until the solution reacts with the PCB. Notice that the printed circuit board changes color.
e. Etch the layout on the printed circuit board.
f. When the layout is clear and visible, wash the PCB with water. Place the etched circuit board on a ferric chloride solution to dissolve unwanted copper by shaking the container. Wash the board with water and put to dry when all unwanted copper is removed.
g. Test all the connections of the circuit board using the VOM. Check for continuity.
h. Drill holes on the board according to the proper layout of the components.
i. Assemble all the components needed for the design except for the microcontroller.
j. Solder all the components on the board properly.

INTEGRATION OF HARDWARE AND SOFTWARE

1. Using a PIC16F84A device programmer, upload the HEX file into the PIC16F84A. The step is often called "burning".

2. Put into position the microcontroller on the corresponding IC socket on the circuit board.
3. Place and screw the circuit board inside the casing.
4. Measure the dimensions of the switch, push buttons, DB-9 connector slot for power supply cable hole. Outline the measurement on the plastic casing and cut the edges on the marked outline. Mount the components properly and screw it on.
5. Construct a frame case for the fiber-optic proximity sensor head and amplifier. Place the stepper motor on top of the frame case. The stepper motor is connected to a movable rod which will serve as the point of reference.
6. Measure and cut two 3 1/2-inch-long pieces of plastic to make arches. For each arch, use a compass to draw a 1-inch-radius semicircle at the center of one long edge, to form a 1-inch-high arch on one long side. Then carefully cut the arch.
7. Make sure to mount properly the fiber-optic proximity sensor heads and amplifiers.
8. Screw securely one arch in the movable rod and the other half at the bottom of the frame. The finger is placed in this setup for measurement.
9. Connect all the ports from the circuit board to the stepper motor and amplifier.

PC INTERFACING

1. Establish and analyze the software requirements for the database software.
2. Generate a program code that could store customer's information and sizes of fingers.
3. Using UART (Universal Asynchronous Receiver/Transmitter) establish a code that involves connecting the design prototype to the computer serially.

TESTING AND DEBUGGING

1. This phase demonstrates if the design is working according to its functions and objectives.
2. Verify the program if it works as expected. Troubleshoot, if necessary.

Hardware Design

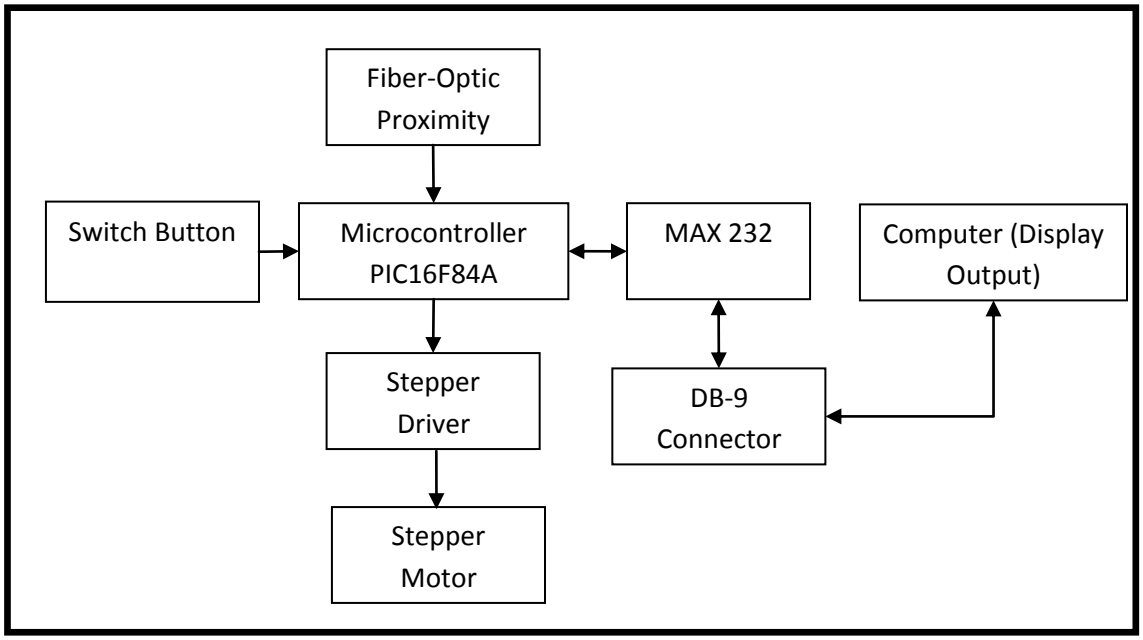

Figure 3.3: Block Diagram Of Hardware Design

As seen in Figure 3.3 Block Diagram, when the Fiber Optic Proximity Sensor approached the desired sensitivity of the light it will send signal to the microcontroller and the output wherein the size of the finger will be displayed on the computer.

Circuit Design

Figure 3.4 shows the circuit diagram of the whole prototype design.

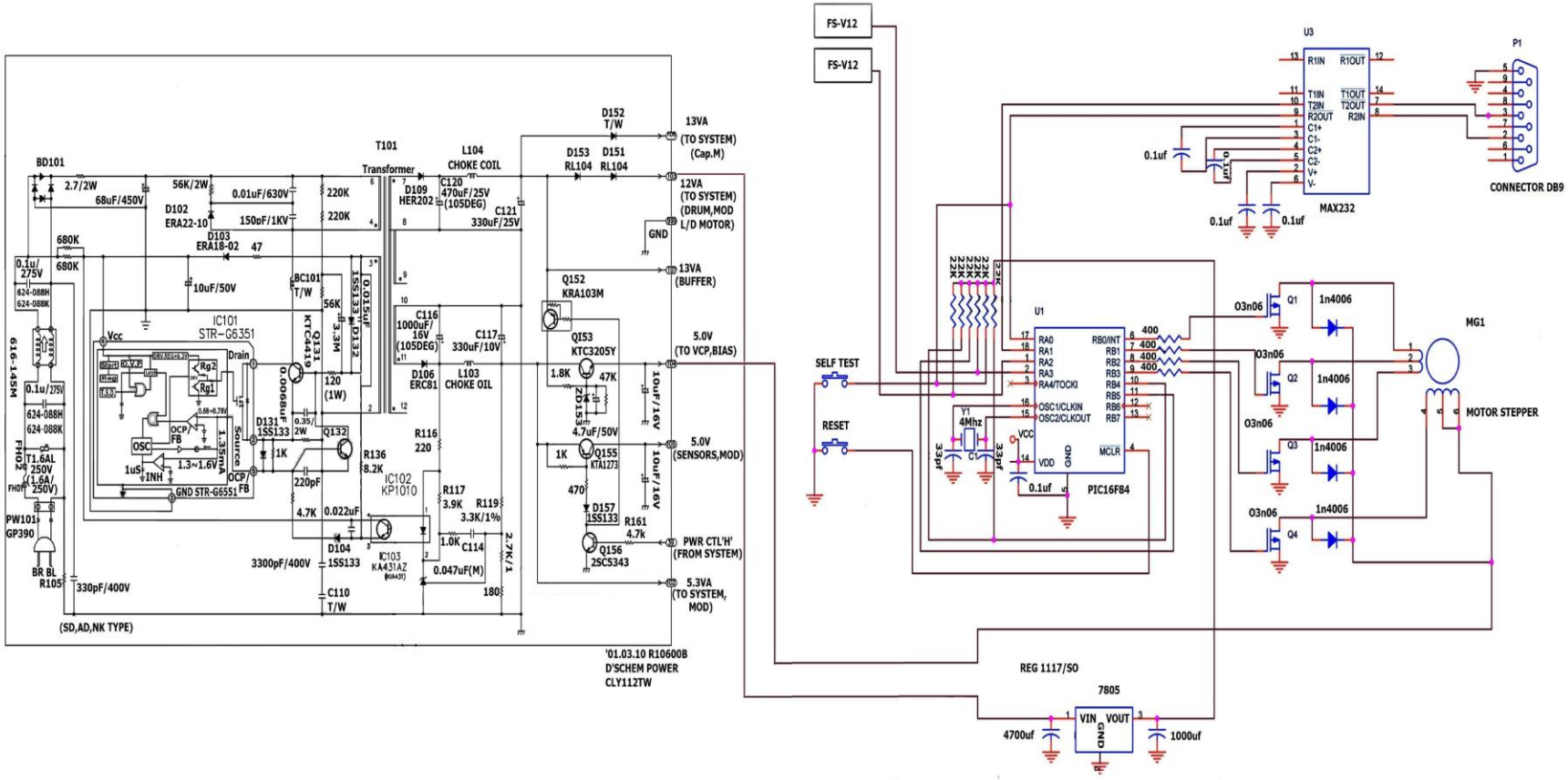

Figure 3.4: Schematic Diagram Of Hardware Design

Hardware Components

The following components in the schematic diagram seen in Figure 9 are discussed below:

1. **PIC16F84A Microcontroller** – The general components of the PIC16F84A microcontroller consisted of program memory, data memories (EEPROM, RAM), I/O ports, free-run timer and CPU. The microcontroller served as a device controlling the movement of the stepper motor. The I/O ports served as physical connections between the microcontroller and the computer.
2. **Stepper Motor** – Stepper motor system consisted of a permanent magnet rotating shaft called the rotor, and electromagnets on the stationary portion that surrounded the motor called the stator. Stepper motors operated differently from other motors; rather than voltage being applied and the rotor spun smoothly, stepper motors turned on a series of electrical pulses to the motor's windings. Each pulse rotated the rotor by an exact degree. The frequency of the pulse train controlled the velocity of the motor, where the number of pulses determined the length of the movement of the rod to the reference point.
3. **MAX232** – MAX232 system is a standard serial interfacing for PC. The system was used to serially interface the design prototype to the computer. It is needed to convert the TTL (Transistor-Transistor Logic) levels from the microcontroller to the 12 V power supply for the computer.

4. **Fiber-Optic Proximity Sensor (Head/Amplifier)** - Fiber optic proximity sensors used to detect the proximity of target objects. For position measurement sensors, this was the distance range over which the position vs. output response which was linear and stable. The minimum detectable object was the smallest sized object detectable by the sensor. The response time was the time from target object entering detection zone to the production of the detection signal.
5. **Switch Mode Power Supply** – It incorporated power handling electronic components which were continuously switched on and off with high frequency. It effectively connects and disconnects energy storing inductors to and from the input source.
6. **DB9 Connector** - The DB9 connector is mainly used for serial connections, allowing for the asynchronous transmission of data as provided for by standard RS-232 (RS-232C).
7. **DB9 Serial Data Cable** – This is used to provide direct data transfer from a control device to a display device.
8. **Diode 1N4006** - A diode is placed after the stepper motor to avoid feedback effect of the electric charge.
9. **MOSFET 03N06** – It is a device used to amplify or switch electronic signals.
10. **Resistor** – It is used to determine the flow of current where there is high resistance in a circuit the flow of current is small and when the resistance is low the flow of current is large.

11. **Capacitor** – It is a device used for storage of electric charge.
12. **Transformer** – A device that transfers electrical energy from one circuit to another through inductively coupled electrical conductors
13. **Voltage Regulator 7805** - An electrical regulator designed to automatically maintain a constant voltage level.
14. **Power Switch** - An electric switch which energizes or de-energizes an electric load; ranges from ordinary wall switches to load-break switches and disconnecting switches in power systems operating at voltages of hundreds of thousands of volts.
15. **Plug** - A male fitting for making an electrical connection to a live circuit by insertion in a receptacle.
16. **AC Cord** – It is a cable that temporarily connects an electrical appliance to the distribution circuits of an electrical power source via a wall socket or extension cord.

List of Materials

Quantity	Description
2 pcs	Fiber Optic Proximity Sensor Head
2 pcs	Fiber Optic Proximity Sensor Amplifier
1 pc	Unipolar Stepper Motor
1 pc	Max232 IC
3 pcs	Capacitor 0.1µF
1 pc	DB-9 Cable Connector
1 pc	DB-9 Port
1 pc	PIC16F84A Microcontroller
6 pcs	Resistors 22KΩ
4 pcs	Resistors 400Ω
1 pc	Crystal Oscillator 4MHz
2 pcs	Capacitor 33pF
1 pc	Capacitor 0.1µF
4 pcs	MOSFET03N06
4 pcs	Diode 1N4006
1 pc	Switching Mode Power Supply
1 pc	7805 Voltage Regulator
1 pc	Capacitor 4700µF
1 pc	Capacitor 1000µF
2 pcs	Push Buttons
1 pc	Power Switch
1 pc	Power Plug
1 pc	Casing

Table 3.1: List of Materials

The list of components that the proponents have used in creating the design is shown on table 3.1.

Hardware Implementation

The proponents designed the prototype upon completing the research study. They thoroughly selected the components and materials needed to implement the design prototype. The design prototype was tested to different individuals. They compared the results of the automatic ring sizer to the manual ring sizer to show the accuracy of measurement of the prototype.

Software Design

The program for the microcontroller was meant for measuring the finger. The program was created using the MicroC Electronica Compiler that works in C language. The microcontroller controls the movement of the stepper motor, counts the number of revolution made by the stepper motor and displays the generated output to the computer using serial connection. With the MAX232 the system was used to serially interface the design prototype to the computer.

The program for the availability checker database was meant for the client's profile, finger measurements, and ring database. The program was created using Visual Basic 6.0 and Microsoft Access.

Software Component

Basically, the C Language and MicroC Electronica were used for programming the microcontroller and Visual Basic 6.0 for the availability checker database system. After programming, the code for the microcontroller was

compiled to the machine language and the machine code was burned to the microcontroller. The team was able to generate, simulate and program the software for the design with the appropriate features of the programming tool used.

System Flowchart

Figure 3.5 as shown on page 46 is the main system flowchart of the design project. It illustrates how the operation of the system works. The basic function of this design prototype is to measure the sizes of the fingers and to show available rings.

The design prototype must be connected first to the computer using DB9 cable for safety measures. To start the system, press the power button to switch of the device. Then, open the database application of the ring sizer and availability checker. It will proceed to the main window of the database, the administrator must log in first for security purposes. There are three options that a user can choose from: to select customer ring, to manage customer record, or to manage ring record.

If the user chooses an operation to select customer ring, Figure 3.7 on page 48 illustrates the ring selection flowchart. The user selects first the customer's profile from the database. Then, the customer can decide which finger he/she would like to buy a ring for. Once the customer has decided,

he/she can now choose from the available ring designs selection that fits to his/her finger size. Afterwards, the customer can now purchase the ring item.

If the user chooses an operation to manage customer record, Figure 3.6 on page 47 illustrates the customer record flowchart. There are three options that a user can choose from this operation: to add new record; to modify existing record; or, delete existing record. To add a new customer record, the information fields must be filled out first before measuring the finger. Then, the user clicks the first finger variant to be measured. Afterwards, the device should be reset by pressing the reset button on the prototype. Once the prototype is reset, the customer can place the finger properly on the device and press enter. The stepper motor will move and determine the number of revolution the stepper motor made. The number of revolution of the stepper motor is equivalent to the size of the finger in millimeters and is converted to the international standard size of the ring. The stepper motor stops when the fiber optic proximity sensor detects a finger. Since the fiber optic proximity sensor is a non-contact sensor, an offset value is added to the original size. Eventually, press the enter button on the device and the size of the finger is displayed on the computer screen. All fingers must be measured for future references. Lastly, save the new customer record. To edit an existing record, the user chooses a customer profile to be modified. The user can edit the customer's information and the finger sizes. Or, to delete an existing record, the user chooses a customer profile to be deleted.

If the user chooses an operation to manage the ring record, Figure 3.7 on page 48 illustrates the ring record flowchart. There are two options that a user can choose from this operation: to delete existing ring record or to edit an existing rings record. The user can delete existing ring record and indicate the sizes of the available rings. Or, the user can modify an existing ring record.

The system will still continue working every after operation unless the user chose to turn off the device by pressing the power off button.

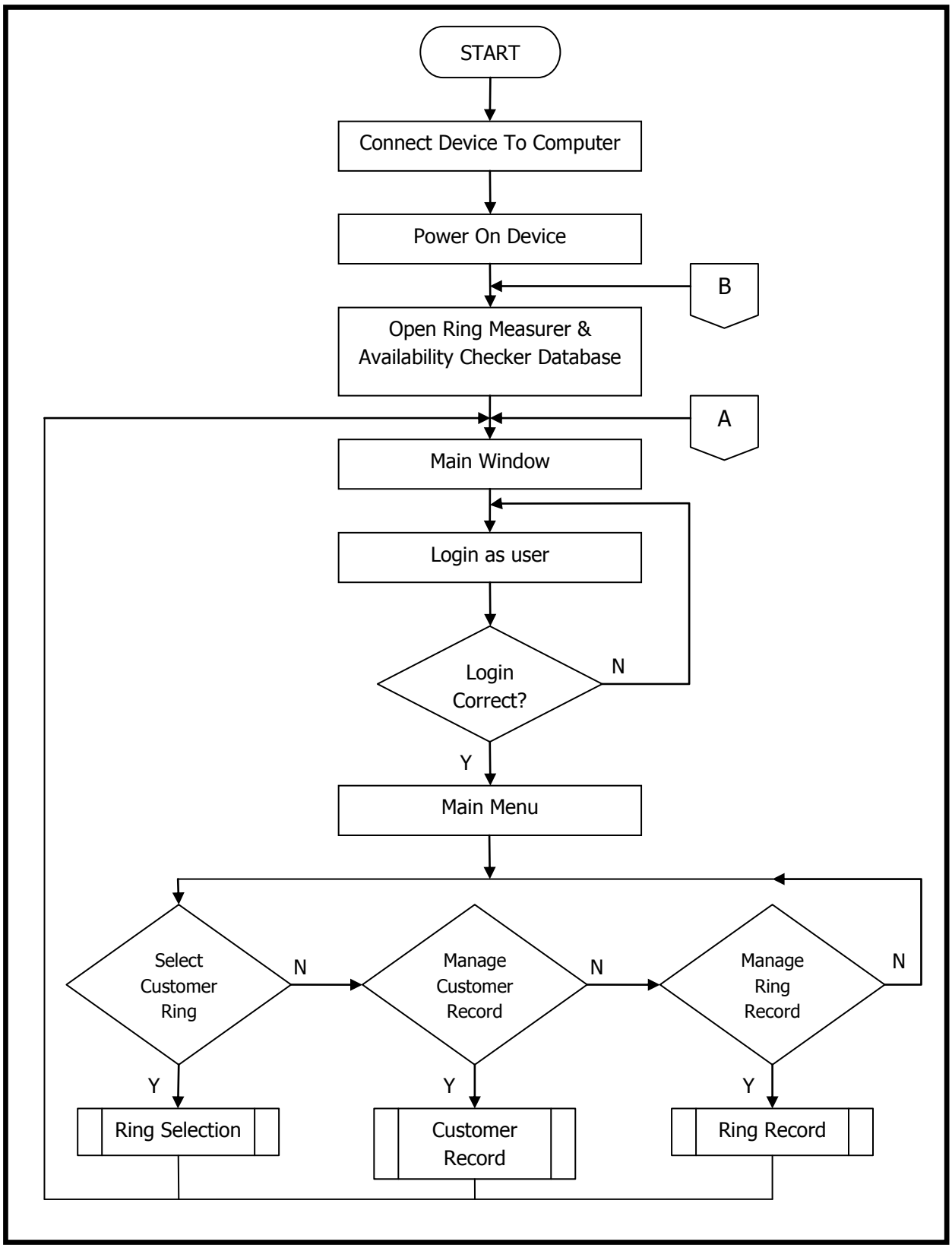

Figure 3.5: Main System Flowchart

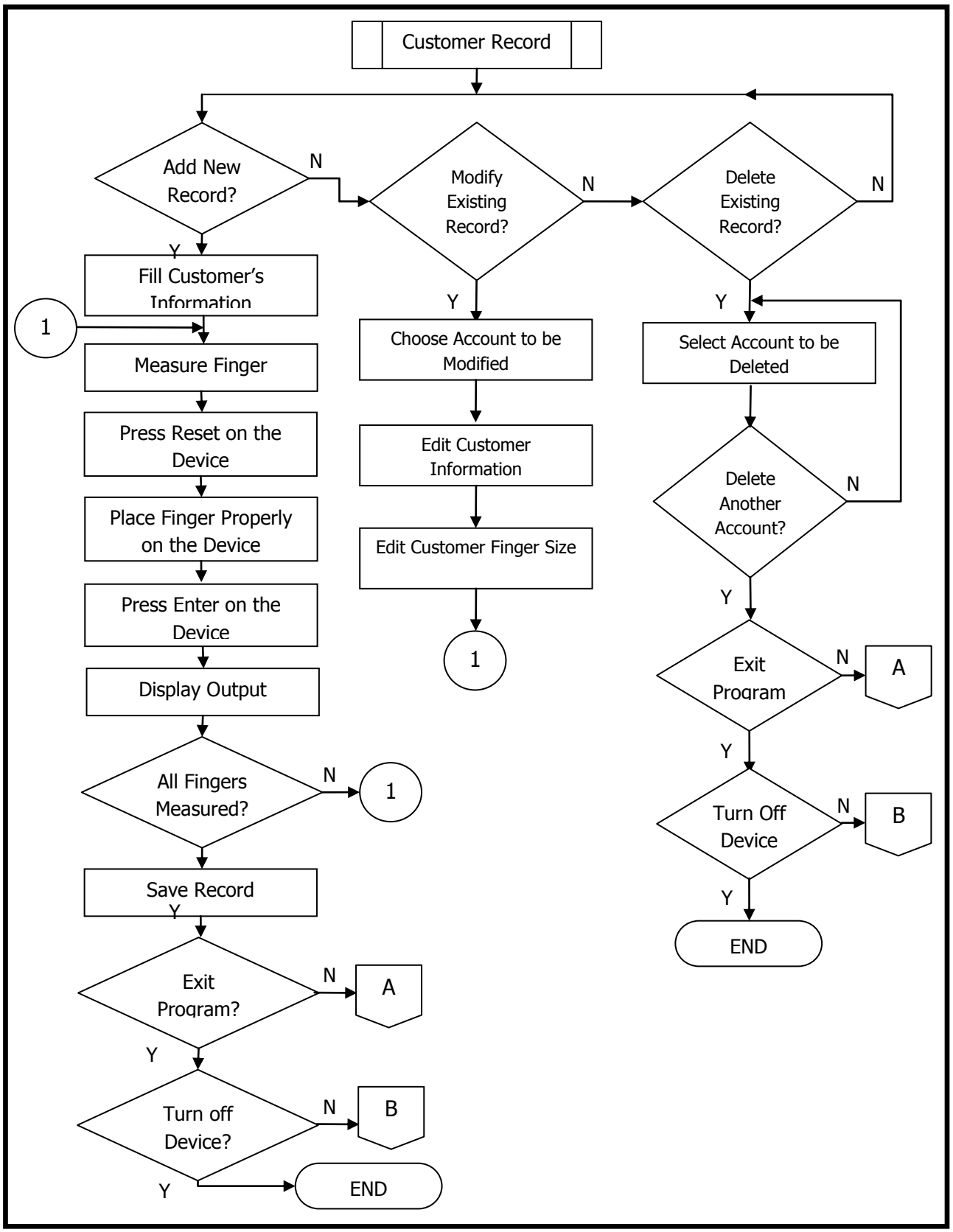

Figure 3.6: Customer Record Flowchart

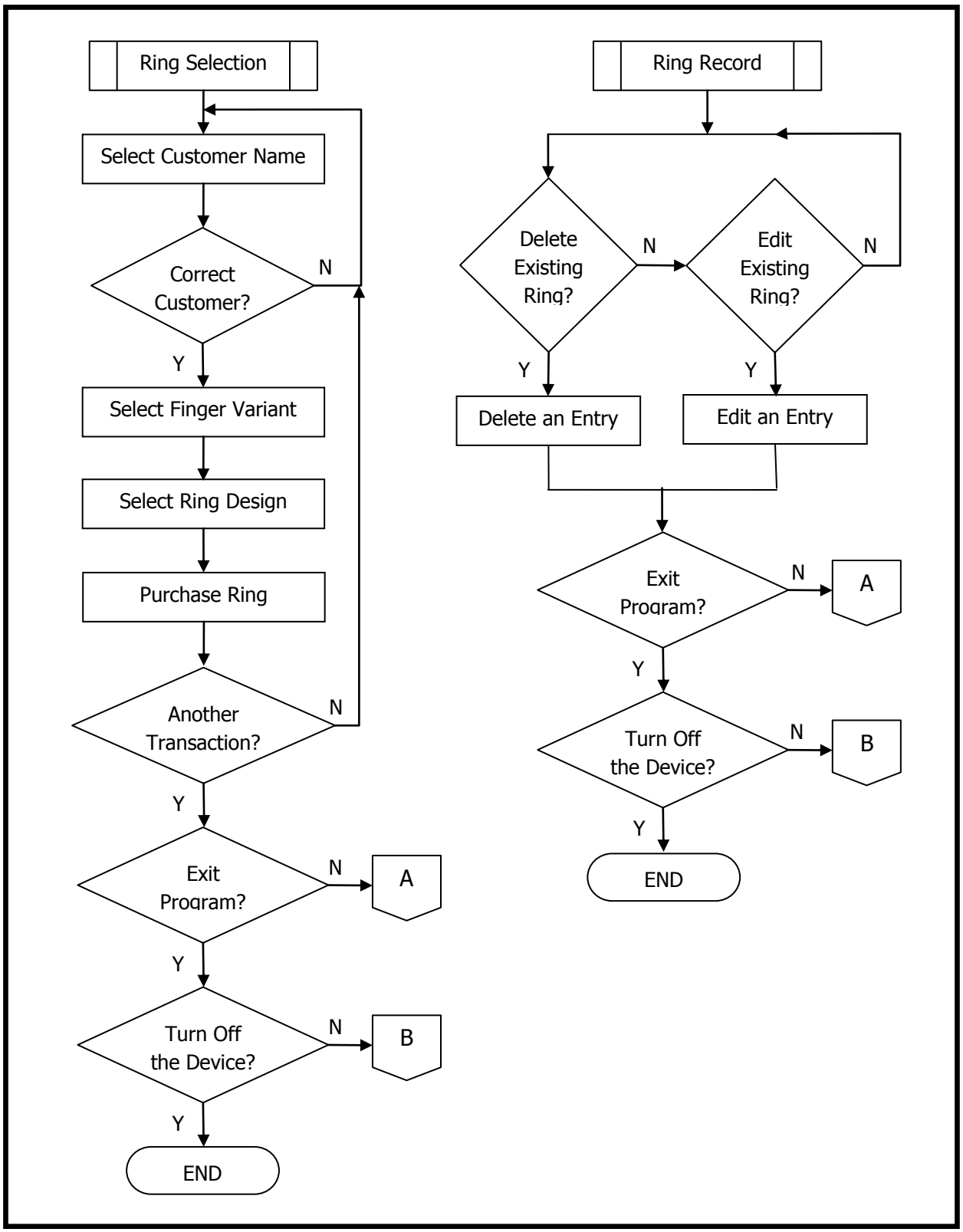

Figure 3.7: Ring Selection & Ring Record Flowchart

Chapter 4

TESTING, PRESENTATION, AND INTERPRETATION OF DATA

The design in this chapter was tested to further determine its functionality and capability in handling the operation of the whole system. This part is important for the design for the proponents to determine and test whether the design would work out well or not. On this part, they can have an idea on the possible outcome of our design. Rigid testing was conducted to verify and check if the expected sizes of finger in the output and the values gathered from the tests would approximately be the same with the real size of a normal finger. Outputs of the tests are shown in Table 4.1.

Expected Results

The expected finger sizes of an individual were shown on this part; the values that the proponents expected from their test results were evidently the same. They assumed that the normal person with normal physique would have the same result compared to manual testing; results vary on how the person would want the ring to fit in his finger.

The proponents conducted tests to determine the functionality of the design and how precise it can measure. One of them performed to measure his finger size using the design and advised to imagine that the ring will be a normal fit; the proponents recommended this because they wanted to somehow get

closer to the exact results, and because results may vary on how fit the ring will be on the finger. The design is an invention on how to measure the size of our finger; this is because of the device the proponents used to trigger the output of their design which is called fiber optic proximity sensor. Since this is a light sensor device they came up with an offset value so that they would be able to determine the accurate size where too many experiments were conducted. They also conducted testing on other manual measuring devices like using the different circular bands they bought beside's mercury drugstore in Quiapo. The trial results are shown in Table 4.1. The first problem the researchers encountered was to determine what the closest accurate offset value was? Due to intensive trial and error experiment they conducted, they were able to determine that the offset value of the design was 3.5 mm. Since the device used was a fiber optic proximity sensor that triggered when the reflection of the light was blocked by an object. Table 4.1 below showed the results of the experiment using 3.5 mm as offset value. Based on the results, the value was almost the same as of the manual ring sizer. The proponents conducted 3 Trials to be able to verify that they have right offset value. On the 3 trials they conducted the results they got was very close to each other, which showed how accurate was the design.

Table 4.1: Trial Results in Standard Size

FINGER VARIANT	MANUAL MEASUREMENT (Ring Sizer)	AUTOMATIC RING SIZER (Trial 1)	AUTOMATIC RING SIZER (Trial 2)	AUTOMATIC RING SIZER (Trial 3)
LEFT PINKIE	5.5	5.5	5.5	5.5
LEFT RING	7.75	7.75	7.5	7.75
LEFT MIDDLE	9.25	9.25	9	9
LEFT INDEX	9.25	9.75	9.5	9.5
LEFT THUMB	11	10.75	11.5	11.75
RIGHT PINKIE	5.5	5.25	5.25	5.5
RIGHT RING	8.25	8	8	8
RIGHT MIDDLE	9.25	9	9.25	9.25
RIGHT INDEX	9.25	9.75	9.75	9.75
RIGHT THUMB	11	11.75	12	12

Table 4.1 showed the results on the 3 trials obtained by converting the results on Table 4.1.1, Table 4.1.2 and Table 4.1.3 by its diameter and the value was in millimeters. It also showed the difference of the manual ring sizer to the automatic ring sizer, and the difference was very minimal.

Table 4.1.1: Equivalent Measurement in Diameter (mm)

First Trial

FINGER VARIANT	MANUAL MEASUREMENT (Ring Sizer)	AUTOMATIC RING SIZER (Trial 1)	DIFFERENCE
LEFT PINKIE	16.1	16.1	0 mm
LEFT RING	17.93	17.93	0 mm
LEFT MIDDLE	19.15	19.15	0 mm
LEFT INDEX	19.15	19.56	0.41 mm
LEFT THUMB	20.57	20.37	0.2 mm
RIGHT PINKIE	16.1	15.9	0.2 mm
RIGHT RING	18.34	18.14	0.2 mm
RIGHT MIDDLE	19.15	18.95	0.2 mm
RIGHT INDEX	19.15	19.56	0.4 mm
RIGHT THUMB	20.57	21.18	0.61 mm

Table 4.1.2: Equivalent Measurement in Diameter (mm)

Second Trial

FINGER VARIANT	MANUAL MEASUREMENT (Ring Sizer)	AUTOMATIC RING SIZER (Trial 2)	DIFFERENCE
LEFT PINKIE	16.1	16.1	0
LEFT RING	17.93	17.73	0.2
LEFT MIDDLE	19.15	18.95	0.2
LEFT INDEX	19.15	19.35	0.2
LEFT THUMB	20.57	20.98	0.41
RIGHT PINKIE	16.1	15.9	0.2
RIGHT RING	18.34	18.14	0.2
RIGHT MIDDLE	19.15	19.15	0
RIGHT INDEX	19.15	19.56	0.4
RIGHT THUMB	20.57	21.39	0.82

Table 4.1.3: Equivalent Measurement in Diameter (mm)

Third Trial

FINGER VARIANT	MANUAL MEASUREMENT (Ring Sizer)	AUTOMATIC RING SIZER (Trial 2)	DIFFERENCE
LEFT PINKIE	16.1	16.1	0
LEFT RING	17.93	17.93	0
LEFT MIDDLE	19.15	18.95	0.2
LEFT INDEX	19.15	19.35	0.2
LEFT THUMB	20.57	21.18	0.61
RIGHT PINKIE	16.1	16.1	0
RIGHT RING	18.34	18.34	0
RIGHT MIDDLE	19.15	19.15	0
RIGHT INDEX	19.15	19.56	0.4
RIGHT THUMB	20.57	21.39	0.82

Since the proponents got the results from the manual measurement and ring sizer, they decided to test the results and compare the values of the experiment. The table above showed differences of their experimentations using the manual ring sizer they bought from the design, the automatic ring sizer and availability checker.

Difference Formula

Difference = Manual Measurement, mm.(Ring Sizer) – Automatic Ring Sizer, mm.

The outputs shown in the experimentation illustrated the accuracy of the Automatic Ring Sizer and Availability Checker design prototype. Although the proponents used an offset value, the design prototype invented was the best design invented to measure a person's finger size. But in the end, the individual will decide on how the ring will fit in his/her finger.

Table 4.3: Automatic Ring Sizer Test Result

FINGER VARIANT	MANUAL	AUTOMATIC	MANUAL in (mm)	AUTOMATIC in (mm)	DIFFERENCE in (mm)
L. PINKIE	5.5	5.5	16.1	16.1	0 mm
L. RING	9	9.25	18.95	19.15	0.2 mm
L. MIDDLE	11	11.5	20.57	20.98	0.41 mm
L. INDEX	11	11.25	20.57	20.78	0.21 mm
L. THUMB	11	11.5	20.57	20.98	0.41 mm
R. PINKIE	5.5	5.25	16.1	16.1	0 mm
R. RING	9.25	9.25	19.15	19.15	0 mm
R. MIDDLE	11	11.75	20.57	21.18	0.61 mm
R. INDEX	11	11.75	20.57	21.18	0.61 mm
R. THUMB	10.5	10.25	20.17	19.96	0.21 mm

Table 4.3 below showed the result of a test we conducted with one of the proponents' friends who was amazed with the invention developed. The proponents were delighted that the prototype demonstrated how innovation technology can be.

Chapter 5

CONCLUSION AND RECOMMENDATION

Conclusion

By following the methodology of the design, a device that could automatically and accurately measure the finger size was created. The proponents concluded the following:

1. The use of fiber optic proximity sensor mounted on the design to measure the exact size of a finger was effective since the test results on Table 4.3 showed an efficient output.
2. The database created was useful in storing customer's profile and finger sizes. This could be used not only in the existing market but also for future references.
3. The device was successfully connected to the desktop by means of the serial cable communication.

Recommendation

Some features that can be added or changed to the Automatic Ring Sizer and Availability Checker are the following:

1. The appearance of the device should be changed so that fingers will be comfortably placed while being measured.

2. A sensor that can accurately measure an object's circumference can be used instead of the sensor that is used in the device.
3. The design can be improved in the future by measuring smaller finger sizes than 15 mm finger diameter, and bigger finger sizes larger than the 25 mm diameter size.
4. The device may also be improved by the use of parallel cable communication or USB connection.
5. The device may also be developed by adding function which will measure the circumference of the finger, rather than the diameter alone. This will make the design more accurate.
6. The software program may be improved or developed using a Web-Based Application so that the records of the customer can be viewed online. This allows the user to view his/her finger sizes information in any place that has internet connection.
7. The software program may also be improved by having levels of hierarchy for the account logging – a level for the administrat or, the cashier/counter, and the customer.
8. The software program may also be improved by having a module for adding new ring information.
9. The program may be added with the feature of generating sales report.
10. Fingers should be measured at normal temperature.

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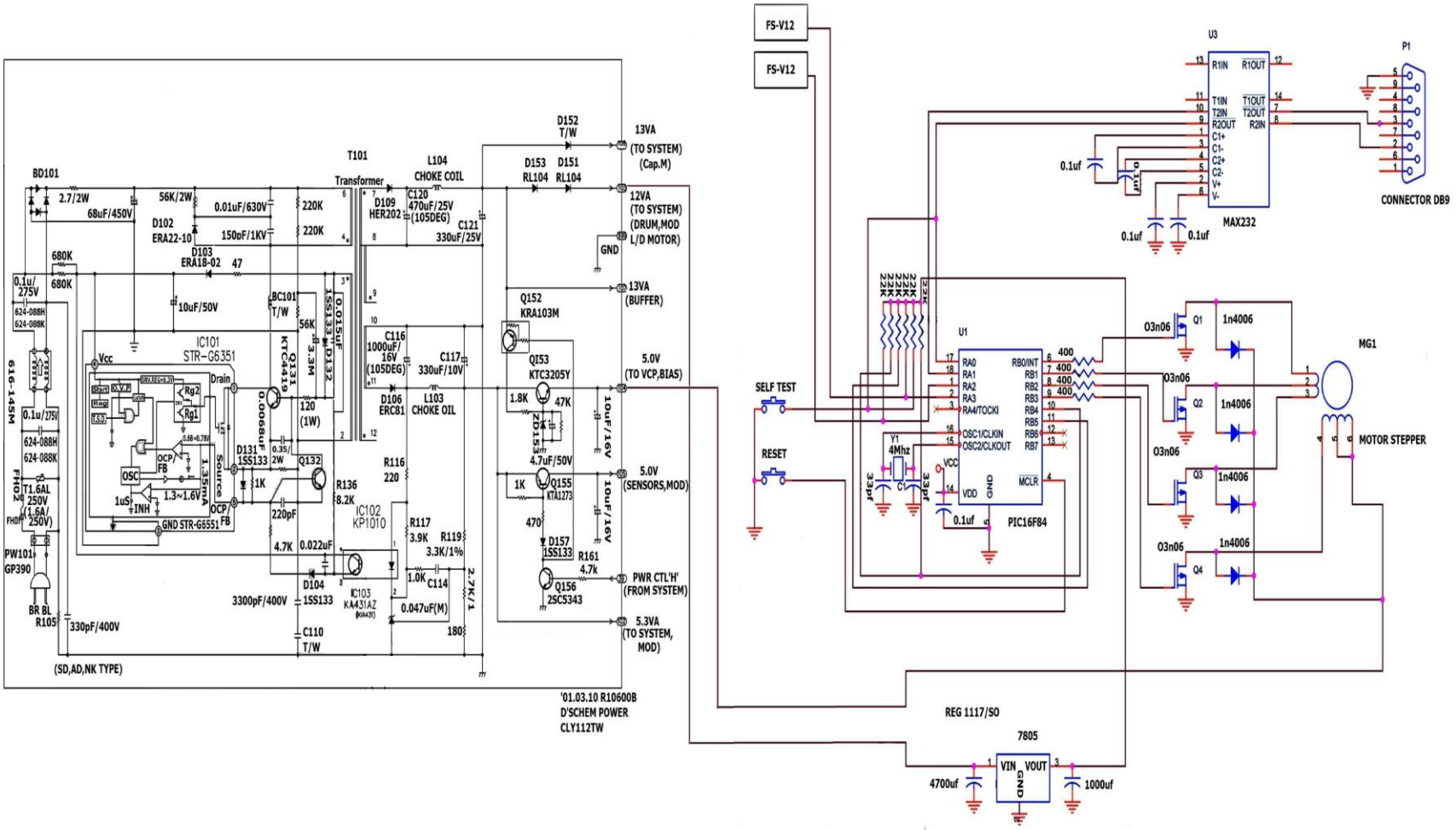
APPENDIX A

Circuit / Schematic Diagram



Schematic Diagram Of Hardware Design

APPENDIX B

Source Code

(PIC16F84A Microcontroller)

```
void initPorts(void);
void setMotor(char myDir);
unsigned int stepCtr=0,tempSC=0;
unsigned short *myByte,ctr;
unsigned short stepperStep;
char mySendChars[7];
void main(void)
     {

     initPorts();
     //initialize stepper motor;

     Soft_Uart_Init(PORTA,1,0,9600,0);

     setMotor('R');
     Soft_Uart_Write('R');
     Soft_Uart_Write('R');

     for(ctr=0;ctr<7;ctr++)
        mySendChars[ctr]=0;

     do
     {
     stepCtr=0;

     do{
     if(PORTA.F1==0)break;
     }while(1);
     setMotor('R');
```

```
      Soft_Uart_Write('F');
      Soft_Uart_Write('F');

      do{
      if(PORTA.F1==0)break;
      }while(1);

      stepCtr=0;
      setMotor('F');



       IntToStr(stepCtr, mySendChars);
       tempSC=stepCtr;
       for(ctr=0;ctr<7;ctr++)
            {
            Soft_Uart_Write(mySendChars[ctr]);
            Delay_ms(50);
            }
      }while(1);



      }

void initPorts(void)
      {
      TRISA=0x0E;
      TRISB=0xF0;
      PORTA=0x00;
      PORTB=0x00;
```

```
      }


void setMotor(char myDir)
      {
       switch(myDir)
      {
      case 'R': //REVERSE



           stepperStep=8;


           while(1)
                {


                 PORTB&=0xF0;
                 PORTB|=stepperStep;
                     //Delay_ms(10);
                   if(stepperStep==1)
                    stepperStep=8;
                   else
                    stepperStep=stepperStep>>1;


                if(PORTA.F2==1)
                  {
                  PORTB&=0xF0;
                      //Delay_ms(500);
                  break;
                  }
                }
```

```
      break;

case 'F': //FORWARD

      stepperStep=1;

      while(1)
            {
             PORTB&=0xF0;
             PORTB|=stepperStep;
                 Delay_ms(10);
               if(stepperStep==8)
                stepperStep=1;
               else
                stepperStep=stepperStep<<1;

            stepCtr=stepCtr+1;

            if((PORTA.F3==0) || (stepCtr==2000))
              {
              PORTB&=0xF0;
                  Delay_ms(500);
              break;
              }
            }

      break;
}
}
```

APPENDIX C

Source Code

(Ring Calibration and Finger Diameter Measurement System)

```
Private Sub mscRing_OnComm()

Dim myText As String

Select Case mscRing.CommEvent

    Case comEvReceive

        myText = mscRing.Input

        Select Case myText

            Case "RR"

                If GetMyTransType = "WAITING" Then
                  setMyTransType ("READY")
                  mscRing.Output = "U"
                Else
                MsgBox "An Error occured while processing your
transaction." & _
                           vbCrLf & _
                "Please restart your transaction from the beginning.",
vbApplicationModal + vbInformation, GetMyVersionID

                End If

            Case "FF"

                   If GetMyTransType = "WAITING" Then

                   MsgBox "Please PRESS RESET on the DEVICE.",
vbApplicationModal + vbInformation, GetMyVersionID
```

```
                    setMyTransType ("WAITING")

                    Exit Sub

                    ElseIf GetMyTransType = "READY" Then

                    MsgBox "Please put your " & lblMyNormalLabels(6 +
GetFinger).Caption & " on the device and press 'OK'" _
                            , vbApplicationModal + vbInformation,
GetMyVersionID

                    setMyTransType ("PROCESSING")
                    mscRing.Output = "U"
                    mscRing.RThreshold = 6

                    End If

            Case Else

                If mscRing.RThreshold > 2 Then
                  mscRing.RThreshold = 2
                  myMeasurement = 20 - (CDbl(myText) / 200)
                  frmWidgetMOffset.Show vbModal

                If mypl.GetConvertedSize(CStr(myMeasurement),
cMeasurement) = True Then

                    txtMyText(7 + GetFinger).Text = cMeasurement

                Else
```

```
                    MsgBox "Measurement Error. Unsupported Size." &
Chr(10) & _
                    "Measurement + Offset in mm: " & myMeasurement,
vbApplicationModal + vbCritical, GetMyVersionID

                End If

                myText = mscRing.Input

                myText = ""

                Else

                MsgBox "An Error occured while processing your
transaction." & _
                            vbCrLf & _
                            "Please restart your transaction from the
beginning.", vbApplicationModal + vbInformation, GetMyVersionID

                End If

        End Select

End Select

End Sub

Private Sub optGender_Click(Index As Integer)

    txtMyText(4).Text = optGender(Index).Caption
```

```
End Sub


Private Sub txtMyText_Click(Index As Integer)


    If Index > 6 And Index < 17 Then


        If MsgBox("Modify measurements for " & lblMyNormalLabels(Index
- 1).Caption & " ?", vbApplicationModal + vbInformation + vbOKCancel,
GetMyVersionID) = vbOK Then


            SetFinger (Index - 7)


            MsgBox "Please PRESS RESET on the DEVICE after clicking
'OK'.", vbApplicationModal + vbInformation, GetMyVersionID


            setMyTransType ("WAITING")


         End If


    End If


End Sub


Private Sub txtMyText_GotFocus(Index As Integer)


Call mypl.TextBoxFocused(Me, Index, True)


End Sub


Private Sub txtMyText_LostFocus(Index As Integer)


Call mypl.TextBoxFocused(Me, Index, False)
```

```
End Sub


Private Sub btnMyButtons_Click(Index As Integer)


    Select Case Index


    Case 0


    If CheckBlanks = False Then


            MsgBox "One or more required textbox is blank. Please fill
it up before saving data.", vbCritical + vbApplicationModal,
GetMyVersionID


            Exit Sub
     End If


     If IsNumeric(Trim$(txtMyText(17).Text)) = False Then


         MsgBox "INVALID VALUE for Age.", vbCritical +
vbApplicationModal, GetMyVersionID


         Exit Sub


     End If


        Call mypl.ModifyMydata(Me, "txtMyText", "CustomerPRF",
selectedMode, selectedID)


      End Select
```

```
        Unload Me

End Sub

'--Triggers--

Private Function CheckBlanks() As Boolean

    Dim myTextboxes As Control

    For Each myTextboxes In Me

        If TypeOf myTextboxes Is TextBox Then

            If Trim$(myTextboxes.Text) = vbNullString And
myTextboxes.Index <> 0 Then

                CheckBlanks = False

                Exit Function

            End If

        End If

    Next myTextboxes

CheckBlanks = True

End Function
```

APPENDIX D

PIC16F84A Datasheet

18-Pin Enhanced FLASH/EEPROM

8-Bit Microcontroller

MICROCHIP

PIC16F84A

18-pin *Enhanced* FLASH/EEPROM 8-Bit Microcontroller

High Performance RISC CPU Features:

- Only 35 single word instructions to learn
- All instructions single-cycle except for program branches which are two-cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- 1024 words of program memory
- 68 bytes of Data RAM
- 64 bytes of Data EEPROM
- 14-bit wide instruction words
- 8-bit wide data bytes
- 15 Special Function Hardware registers
- Eight-level deep hardware stack
- Direct, Indirect and relative addressing modes
- Four interrupt sources:
  - External RB0/INT pin
  - TMR0 timer overflow
  - PORTB<7:4> interrupt-on-change
  - Data EEPROM write complete

Peripheral Features:

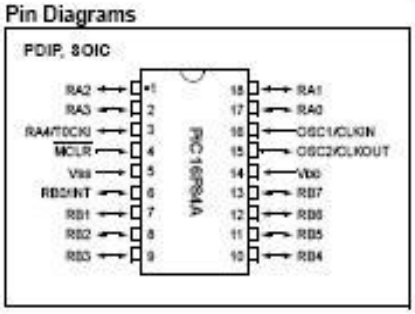
- 13 I/O pins with individual direction control
- High current sink/source for direct LED drive
  - 25 mA sink max. per pin
  - 25 mA source max. per pin
- TMR0: 8-bit timer/counter with 8-bit programmable prescaler

Special Microcontroller Features:

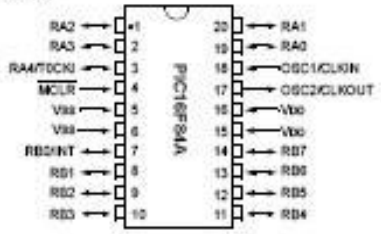
- 10,000 erase/write cycles *Enhanced* FLASH Program memory typical
- 10,000,000 typical erase/write cycles EEPROM Data memory typical
- EEPROM Data Retention > 40 years
- In-Circuit Serial Programming™ (ICSP™) - via two pins
- Power-on Reset (POR), Power-up Timer (PWRT), Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own On-Chip RC Oscillator for reliable operation
- Code protection
- Power saving SLEEP mode
- Selectable oscillator options

Pin Diagrams

PDIP, SOIC



SSOP



CMOS Enhanced FLASH/EEPROM Technology:

- Low power, high speed technology
- Fully static design
- Wide operating voltage range:
  - Commercial: 2.0V to 5.5V
  - Industrial: 2.0V to 5.5V
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 15 µA typical @ 2V, 32 kHz
  - < 0.5 µA typical standby current @ 2V

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1.0 DEVICE OVERVIEW

This document contains device specific information for the operation of the PIC16F84A device. Additional information may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023), which may be downloaded from the Microchip website. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

The PIC16F84A belongs to the mid-range family of the PICmicro® microcontroller devices. A block diagram of the device is shown in Figure 1-1.

The program memory contains 1K words, which translates to 1024 instructions, since each 14-bit program memory word is the same width as each device instruction. The data memory (RAM) contains 68 bytes. Data EEPROM is 64 bytes.

There are also 13 I/O pins that are user-configured on a pin-to-pin basis. Some pins are multiplexed with other device functions. These functions include:

- External interrupt
- Change on PORTB interrupt
- TimerO clock input

Table 1-1 details the pinout of the device with descriptions and details for each pin.

FIGURE 1-1: PIC16F84A BLOCK DIAGRAM

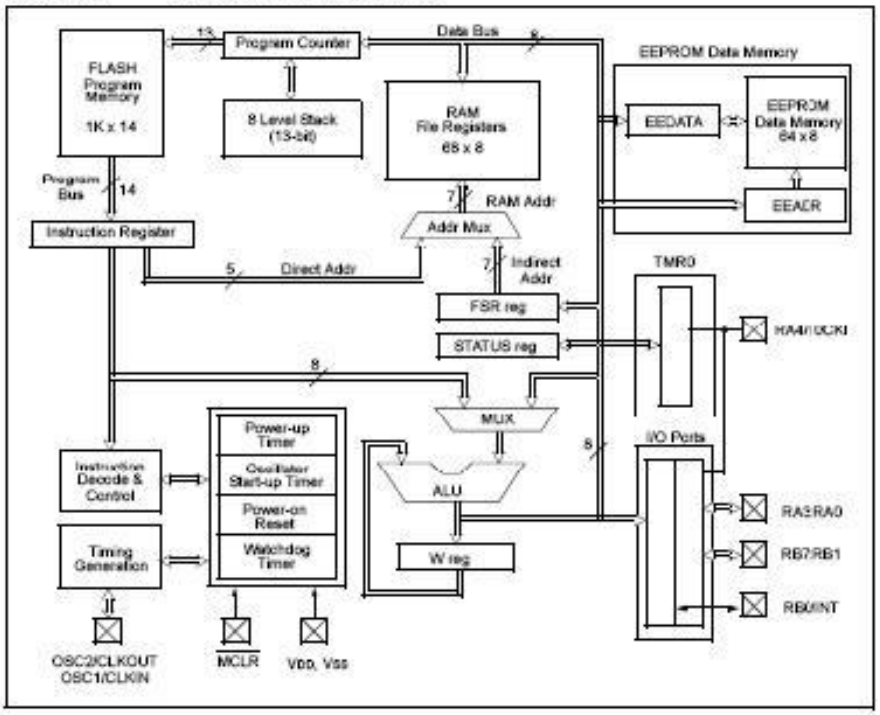

TABLE 1-1: PIC16F84A PINOUT DESCRIPTION

Pin Name	PDIP No.	SOIC No.	SSOP No.	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	16	16	18	I	ST/CMOS(3)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	15	15	19	O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. In RC mode, OSC2 pin outputs CLKOUT, which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
$\overline{MCLR}$	4	4	4	I/P	ST	Master Clear (Reset) input/programming voltage input. This pin is an active low RESET to the device.
						PORTA is a bi-directional I/O port.
RA0	17	17	19	I/O	TTL	
RA1	18	18	20	I/O	TTL	
RA2	1	1	1	I/O	TTL	
RA3	2	2	2	I/O	TTL	
RA4/T0CKI	3	3	3	I/O	ST	Can also be selected to be the clock input to the TMR0 timer/counter. Output is open drain type.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	6	6	7	I/O	TTL/ST(1)	RB0/INT can also be selected as an external interrupt pin.
RB1	7	7	8	I/O	TTL	
RB2	8	8	9	I/O	TTL	
RB3	9	9	10	I/O	TTL	
RB4	10	10	11	I/O	TTL	Interrupt-on-change pin.
RB5	11	11	12	I/O	TTL	Interrupt-on-change pin.
RB6	12	12	13	I/O	TTL/ST(2)	Interrupt-on-change pin. Serial programming clock.
RB7	13	13	14	I/O	TTL/ST(2)	Interrupt on change pin. Serial programming data.
Vss	5	5	5,6	P	—	Ground reference for logic and I/O pins.
VDD	14	14	15,16	P	—	Positive supply for logic and I/O pins.

Legend: I = Input O = Output I/O = Input/Output P = Power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

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2.0 MEMORY ORGANIZATION

There are two memory blocks in the PIC16F84A. These are the program memory and the data memory. Each block has its own bus, so that access to each block can occur during the same oscillator cycle.

The data memory can further be broken down into the general purpose RAM and the Special Function Registers (SFRs). The operation of the SFRs that control the "core" are described here. The SFRs used to control the peripheral modules are described in the section discussing each individual peripheral module.

The data memory area also contains the data EEPROM memory. This memory is not directly mapped into the data memory, but is indirectly mapped. That is, an indirect address pointer specifies the address of the data EEPROM memory to read/write. The 64 bytes of data EEPROM memory have the address range 0h-3Fh. More details on the EEPROM memory can be found in Section 3.0.

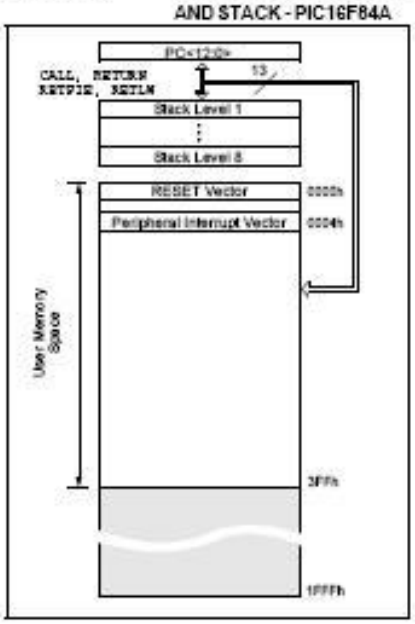
Additional information on device memory may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023).

2.1 Program Memory Organization

The PIC16FXX has a 13-bit program counter capable of addressing an 8K x 14 program memory space. For the PIC16F84A, the first 1K x 14 (0000h-03FFh) are physically implemented (Figure 2-1). Accessing a location above the physically implemented address will cause a wraparound. For example, for locations 20h, 420h, 820h, C20h, 1020h, 1420h, 1820h, and 1C20h, the instruction will be the same.

The RESET vector is at 0000h and the interrupt vector is at 0004h.

FIGURE 2-1: PROGRAM MEMORY MAP AND STACK - PIC16F84A



2.2 Data Memory Organization

The data memory is partitioned into two areas. The first is the Special Function Registers (SFR) area, while the second is the General Purpose Registers (GPR) area. The SFRs control the operation of the device.

Portions of data memory are banked. This is for both the SFR area and the GPR area. The GPR area is banked to allow greater than 116 bytes of general purpose RAM. The banked areas of the SFR are for the registers that control the peripheral functions. Banking requires the use of control bits for bank selection. These control bits are located in the STATUS Register. Figure 2-2 shows the data memory map organization.

Instructions MOVWF and MOVF can move values from the W register to any location in the register file ("F"), and vice-versa.

The entire data memory can be accessed either directly using the absolute address of each register file or indirectly through the File Select Register (FSR) (Section 2.5). Indirect addressing uses the present value of the RP0 bit for access into the banked areas of data memory.

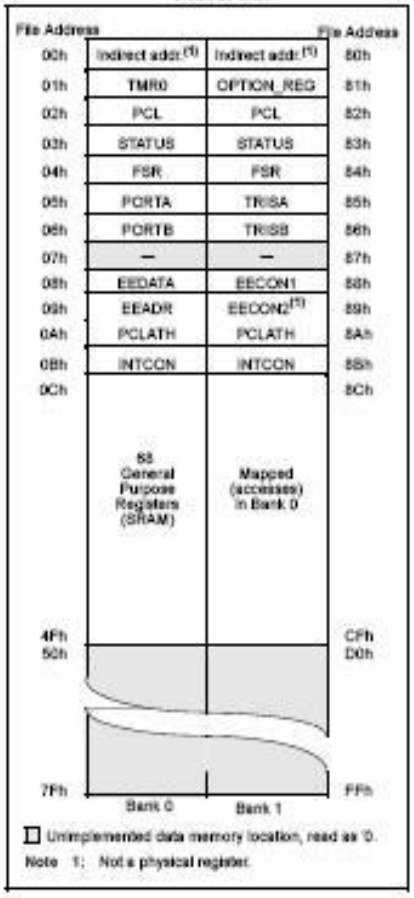
Data memory is partitioned into two banks which contain the general purpose registers and the special function registers. Bank 0 is selected by clearing the RP0 bit (STATUS<5>). Setting the RP0 bit selects Bank 1. Each Bank extends up to 7Fh (128 bytes). The first twelve locations of each Bank are reserved for the Special Function Registers. The remainder are General Purpose Registers, implemented as static RAM.

2.2.1 GENERAL PURPOSE REGISTER FILE

Each General Purpose Register (GPR) is 8-bits wide and is accessed either directly or indirectly through the FSR (Section 2.5).

The GPR addresses in Bank 1 are mapped to addresses in Bank 0. As an example, addressing location 0Ch or 8Ch will access the same GPR.

FIGURE 2-2: REGISTER FILE MAP - PIC16F84A



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APPENDIX E

FS-V12 High Accuracy Fiber Optic Sensors Datasheet

Fiber Optic Proximity Sensor

High Accuracy Fibreoptic Sensors

FS01 Series

Features

- An industry-first dual monitoring system
- Auto and manual calibration
- 20-bit concurrent processing chip
- High accuracy and high power
- Wire-saving 3-line or 1-line connection system

Detecting Distance

Thrubeam – Up to 3,600 mm (with lens)

Diffuse-reflective – Up to 300 mm

Definite-reflective – Up to 14 mm

CE

Description

Dual monitoring system

The FS-V10 Series features both a digital LED indicator, which numerically displays the received light intensity, and a bar LED, which shows the level of detection stability (excess gain). The digital LED indicator can be used to align the optical axis and to display operating conditions during sensor mounting. The bar LED indicates detection stability during operation.

The digital LED indicator is a powerful aid for optical axis alignment.

Auto and manual calibration

In addition to the conventional AUTO SET button, the FS-V10 Series features a Manual Calibration button, which enables fine adjustment. You can start detection after a quick calibration using the AUTO SET button, then make fine adjustments to the sensitivity using the Manual button. Using only the automatic calibration or only the manual calibration will provide satisfactory detection. Even an inexperienced person can make very precise adjustments.

Calibration comparisons	Setting procedure		Fine adjustment		Manual adjustment trimmer
By button	Good	Just press the button for optimal setting.	No good	Sensitivity is fixed. Fine adjustment is impossible.	Sensitivity UP / Sensitivity DOWN / AUTO SET button
By trimmer	No good	Calibration requires experience. Settings vary depending on the operator.	Good	Sensitivity can be set as desired.	
By hybrid calibration	Good	Just press the button for fully automatic calibration.	Good	Sensitivity can be finely adjusted.	

<FS-V10 Series>

NEW 20-bit concurrent processing chip + 12-bit A/D converter
The FS-V10 Series features a newly developed 20-bit concurrent processing chip. This chip can concurrently process 12 types of control including "high-speed calculation of received light intensity", "dual monitor display", and "peak/bottom hold display". Compared to general-purpose CPUs for sequential processing, this chip offers various advantages such as low current consumption, high-speed response, and reduced heat value, resulting in the improvement of overall usability.

Amplifier Variations

Fibreoptic sensors
FS01 Series

Hybrid Calibration Type:
FS-V10 Series
- Dual monitoring function with bar LED and digital display
- Hybrid calibration with Auto SET button and manual adjustment button

One-touch Calibration Type:
FS-T Series
- Fully-automatic calibration by pressing a button
- Green LED light source model FS-T1G is also available

Manual Calibration Type:
FS-M Series
- Fine adjustment in calibration by using a multi-turn trimmer
- Ultra-high-speed response model FS-M1H is also available

Digital Calibration Type:
FS-V1 Series
- Digital monitor function and 2 independent outputs
- Control and adjustment function for 1-line expansion units

FS01 Series features
- High accuracy detection:
  Detects down to 0.01 mm dia wire with thrubeam unit
- High power intensity:
  Detects target at the industry longest 300 mm distance with reflective unit
- Wire-saving connection:
  1-line connection system reduces the wiring labour to 1/2 of conventional method
- Compact size with 8-mm thickness:
  Installing several units requires very small space.

FS01 Series amplifier functional chart

Series		FS-V10	FS-V	FS-T	FS-M
Amplifier model	Main unit	FS-V11	FS-V1	FS-T1	FS-M1
	Expansion unit	FS-V12	—	FS-T2	FS-M2
1-line wire-saving connection system • Main unit supplies power to expansion units, requiring no power supply wire.		✓	✓	✓	✓
Mutual interference suppression • Automatically prevents interference by simply expanding units		✓[1]	✓[2]	✓[2]	✓[2]
4 Automatic calibration modes with a single button • Fully-automatic • Positioning • 2-point • Maximum sensitivity		✓	✓	✓	—
Digital monitor offering 3 display modes • Intensity monitor: showing current received intensity • Limit value display: showing preset limit value • Limit value adjustment: changing limit value digitally		✓	✓	✓[4]	—
2 independent outputs • One unit works as two separate amplifiers		—	✓	—	—
Manual calibration adjustment • Sensitivity finely adjustable		✓[5]	✓[5]	—	✓[5]
Versatile performance with one model • One model covers applications from high-accuracy to high-power intensity		✓[7]	—	—	✓[8]

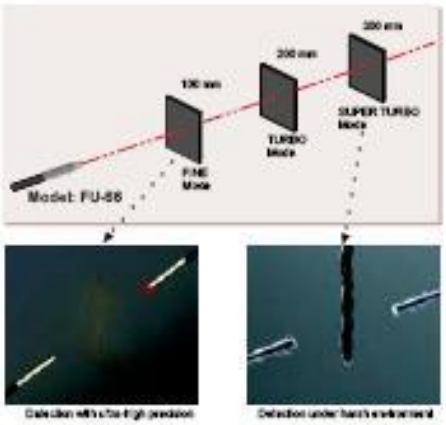
1. FINE mode: Up to 4, TURBO/SUPER-TURBO: Up to 8
2. Up to 4
3. FINE mode: Up to 4, TURBO: Up to 8
4. V1 controls T2.
5. Push-button
6. Trimmer
7. 3 modes: FINE/TURBO/SUPER-TURBO
8. 2 modes: FINE/TURBO

FS01 High Accuracy Fibreoptic Sensors

Functions

From ultra-high precision to ultra-high power: A single unit covers every application

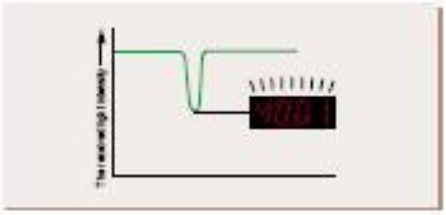
The FS-V10 Series offers three levels of detection to suit the application.



The FS-V10 Series can be used for high-precision detection of wire as thin as 0.01 mm in diameter with a thrubeam type fibre unit. It can also be used for detection in harsh environments where oil or dust exists. Because the FS-V10 Series can work in almost all applications, sensor selection is easy.

Readable digital display of moving target: Peak/bottom hold display

The digital LED monitor can hold the displayed value. The light intensity value of a moving target can be frozen to control the numerical values easily.

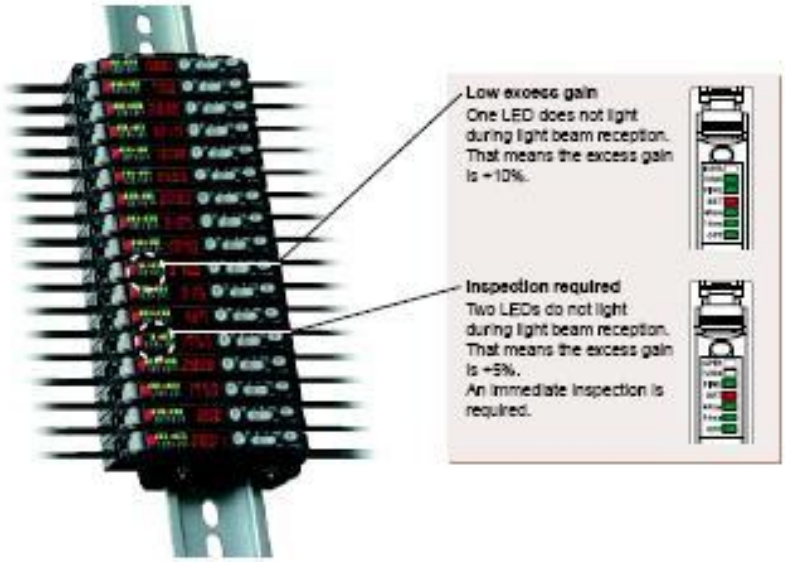


At a glance digital LED monitors interrupted light

The digital LED monitor displays the light quantity at the light-receiving element incrementally from 0 to 4095. This enables you to determine the degree of dust accumulation on the sensor and the deviation in the optical axis.
In addition, checking the change in the light quantity with the digital reading ensures an optimal setting value, improving the detection reliability.

Unstable operating conditions can be discovered at a glance using Bar LED Indicators

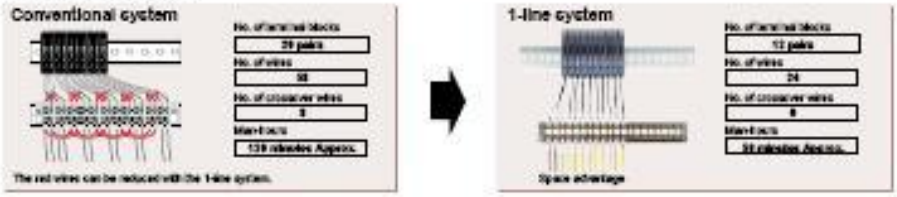
The bar LED indicates detection stability using a 7-level bar LED.
The bar LED shows when maintenance is required at a glance, which is difficult to notice with the digital display.


Low excess gain
One LED does not light during light beam reception. That means the excess gain is +10%.
Inspection required
Two LEDs do not light during light beam reception. That means the excess gain is +5%.
An immediate inspection is required.

1-line wire-saving connection system significantly reduces wiring time

The FS-V10 Series uses the KEYENCE's unique 1-line system.
Power is supplied from the main unit (FS-V11) through the expansion connector so that the expansion units (FS-V12) do not require power cables.

When 10 units are used



Automatic interference prevention

In TURBO/SUPER TURBO mode, up to 8 units can be mounted side-by-side without mutual interference.
(In FINE mode, up to 4 units)

Specifications

Amplifier

FS-V Series

Type		Hybrid calibration (One-touch + manual, digital)			Digital calibration
		Main unit	1-line expansion unit	8-line expansion unit	Main unit
Model	NPN	FS-V11	FS-V12	FS-V10 [1]	FS-V1
	PNP	FS-V11P	FS-V12P	—	FS-V1P
Light source		Red LED			
Response time		250 µs (FINE)/500 µs (TURBO)/1 ms (SUPER TURBO)		410 µs to 1.7 ms [2]	250 µs
Operation mode		LIGHT-ON/DARK-ON (switch-selectable)			
Indicators		Output indicator: Red LED Digital LED monitor: Red LED, 7-segment, 4-digit Bar graph LED monitor: Green/Orange LED [3] Calibration indicator: Orange LED [3]			Output indicators: 2 Red LEDs Digital LCD monitor: LCD (Red/Green LED back-lit) Calibration indicator: Orange LED
Timer function		OFF-delay: 40 ms/10 ms/ Timer OFF (selectable)			ON-delay: 40 ms/ OFF-delay: 40 ms/ Timer OFF (switch-selectable)
Control output		NPN or PNP open-collector: 100 mA (40 V) max., Residual voltage: 1 V max. [4]			
Protection circuit		Reverse polarity protection, over-current protection, surge absorber			
Power supply		12 to 24 VDC ±10%			
Current consumption		50 mA max.			
Ambient illumination		Incandescent lamp: 10,000 lux max., Sunlight: 20,000 lux max.			
Ambient temperature		-10 to +55°C [5]			
Housing material		Body/Cover: Polycarbonate			
Weight (including 2-m cable)		Approx. 80 g	Approx. 45 g	Approx. 20 g	Approx. 80 g

1. FS-V10 has no output wire and FS-R3 should be used for sensing output.
2. The response time varies depending on the number of expansion units connected.
3. The orange LED is normally part of the bar graph LED monitor. It is used as a calibration indicator during the setting of the sensitivity.
4. FS-V1 has 2 outputs.
5. When several units are connected, the allowable ambient temperature changes depending on the following conditions.
   To connect several units, be sure to mount them to a DIN rail (metal DIN rail). Make sure that the output current is 20 mA max.
   When 1 to 10 units are connected: -10 to +60°C, When 11 to 16 units are connected: -10 to +45°C

FS-T Series

Type		One-touch calibration			
		Main unit	Colour detection	1-line expansion unit	8-line expansion unit
Model	NPN	FS-T1	FS-T1G	FS-T2	FS-T8
	PNP	FS-T1P	—	FS-T2P	—
Light source		Red LED	Green LED	Red LED	Red LED
Response time		250 µs	250 µs	250 µs	410 µs to 1 ms [1]
Operation mode		LIGHT-ON/DARK-ON (switch-selectable)			
Indicators		Output indicator: Red LED, Stable operation indicator: Green LED, Calibration indicator: Orange LED			
Timer function		ON-delay: 40 ms, OFF-delay: 40 ms, Timer OFF (switch-selectable)			
External calibration input signal		Non-voltage input (contact, solid state)		—	—
Control output		NPN or PNP:100 mA max. (40 V max.), Residual voltage: 1 V max. [2]			
Stability output		NPN or PNP: 50 mA max. (40 V max.), Residual voltage: 1 V max. [3]			
Protection circuit		Reversed polarity protection, over-current protection, surge absorber			
Power supply		12 to 24 VDC ±10%	12 to 24 VDC ±10%	12 to 24 VDC ±10% [4]	12 to 24 VDC ±10% [4]
Current consumption		35 mA max.	35 mA max.	35 mA max.	35 mA max.
Ambient light		Incandescent lamp: 10,000 lux max., Sunlight: 20,000 lux max.			
Ambient temperature		-10 to +55°C	-10 to +55°C	-10 to +55°C	-10 to +55°C
Housing		Body/Cover: Polycarbonate	Body/Cover: Polycarbonate	Body/Cover: Polycarbonate	Body/Cover: Polycarbonate
Weight (including 2-m cable)		Approx. 75 g	Approx. 75 g	Approx. 40 g	Approx. 20 g

1. The response speed varies depending on the number of expansion units connected.
2. The FS-T2/T8/M2/M8 have no control output.
3. Only the FS-T1/M1 provide stability outputs. Stability outputs for the FS-T2/T8/M2/M8 are output from the FS-T1/M1 or FS-R3.
4. Power to the FS-T2/T8/M2/M8 is supplied through the FS-V1/V1/T1/M1 or FS-R3.

FS-M Series

Type		Manual calibration			
		Main unit	1-line expansion unit	High-speed response	0-line expansion unit
Model	NPN	FS-M1	FS-M2	FS-M1H	FS-M0
	PNP	FS-M1P	FS-M2P	—	—
Light source		Red LED	Red LED	Red LED	Red LED
Sensitivity adjustment/ Mode selection		8-turn trimmer (with indicator), FINE/TURBO (switch-selectable)			
Response time		250 µs (FINE), 500 µs (TURBO)	250 µs (FINE), 500 µs (TURBO)	20 µs (FINE), 50 µs (TURBO)	410 µs to 1.2 ms [1]
Operation mode		LIGHT-ON/DARK-ON (switch-selectable)			
Indicators		Output indicator: Red LED, Stable operation indicator: Green LED			
Timer function		ON-delay: 40 ms, OFF-delay: 40 ms, Timer OFF (switch-selectable)			
Control output		NPN or PNP: 100 mA max. (40 V max.), Residual voltage: 1 V max. [3]			
Stability output		NPN or PNP: 50 mA max. (40 V max.), Residual voltage: 1 V max. [3]			
Protection circuit		Reversed polarity protection, over-current protection, surge absorber			
Power supply		12 to 24 VDC ±10%	12 to 24 VDC ±10% [4]	12 to 24 VDC ±10%	12 to 24 VDC ±10% [4]
Current consumption		35 mA max.	35 mA max.	35 mA max.	35 mA max.
Ambient light		Incandescent lamp: 10,000 lux max., Sunlight: 20,000 lux max.			
Ambient temperature		-10 to +55°C	-10 to +55°C	-10 to +55°C	-10 to +55°C
Housing		Body/Cover: Polycarbonate	Body/Cover: Polycarbonate	Body/Cover: Polycarbonate	Body/Cover: Polycarbonate
Weight (including 2-m cable)		Approx. 75 g	Approx. 40 g	Approx. 20 g	Approx. 20 g

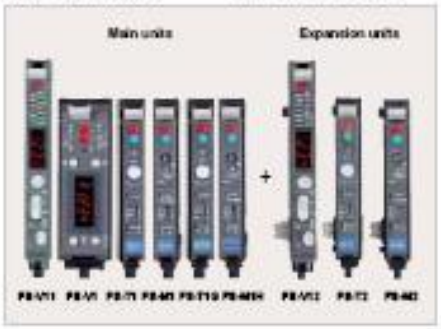
1. The response speed varies depending on the number of expansion units connected.
2. The FS-T3/M0 have no control output.
3. Only the FS-T1/M1 provide stability output. Stability outputs for the FS-T2/T3/M2/M0 are output from the FS-T1/M1 or FS-R0.
4. Power to the FS-T2/T3/M2/M0 is supplied through the FS-V11/V1/T1/M1 or FS-R0.

Amplifier Function

1-line connection amplifiers reduce wiring and labour

Up to 16 expansion units can be connected to a single main unit and can be freely combined.

FS-V11 :Hybrid calibration
FS-V1 :Multi-functions and digital calibration
FS-T1 :One-touch calibration
FS-M1 :Manual calibration
FS-T1G :Green LED light source
FS-M1H :High-speed response
FS-V12 :Hybrid calibration
FS-T2 :One-touch calibration
FS-M2 :Manual calibration



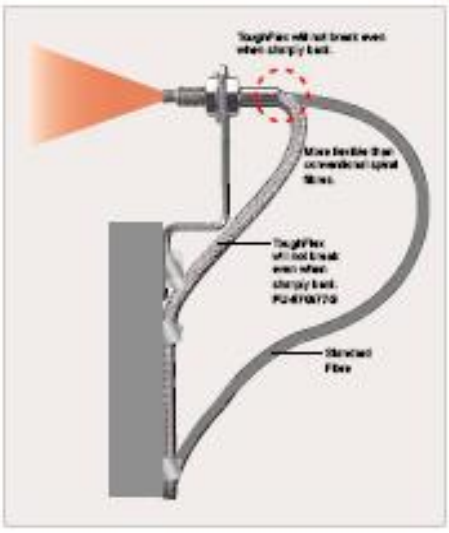
0-line connection units eliminate wiring and labour

The innovative 0-line connection system only requires an FS-R0 connector unit and a cable with a MIL connector for wiring. The units can be easily connected to an I/O card of a PLC (programmable controller) or special board. Units can be freely combined to suit the application.

FS01 High Accuracy Fibreoptic Sensors

ToughFlex Fibre Principle

Keyence has developed the toughest fibre unit series by bundling multiple core fibres of 66 µm diameter. These fibres will work normally without any malfunction even when they are bent to a minimum radius or when they are hit or pulled suddenly.
Keyence has also maintained a long detecting distance while using this unique design. Including focused small spot model, area detection model, ultra-long detecting distance model, and thin sleeve models, every application can be improved with maintenance efficiency.
Plus, the latest armoured model is sheathed by a flexible stainless steel jacket to protect the fibre from daily wear and exposure to harsh environmental conditions.


ToughFlex will not break even when sharply bent.
More flexible than conventional spiral fibres.
ToughFlex will not break even when sharply bent. FU-67G/77G
Standard Fibre

Conventional fibre

A standard fibre will easily break.

A single-core fibre exposed to excessive bending will easily break.

ToughFlex fibre

ToughFlex will not break even when sharply bent.

The 217-core fibre is hardly affected by excessive bending.

ToughFlex Fibre Features

Tough even when entangled

Even if the fibre unit becomes entangled, the fibre unit and the base of the head will continue to perform.

Ready for immediate use

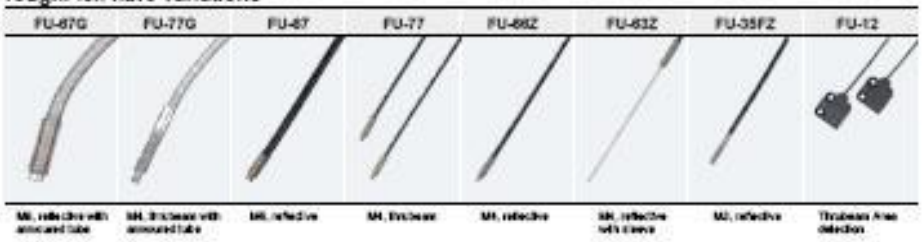
Armoured ToughFlex provides a cost and labour savings by eliminating the need for protective tubing.

Shock-resistant

The fibre unit and the base of the head will continue to perform even when dropped or struck by a tool.

More flexible than conventional spiral fibres

ToughFlex fibre variations

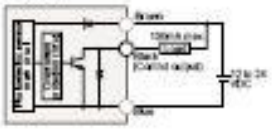


Input/Output Circuits

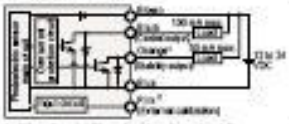
Output circuit

NPN

FS-V11

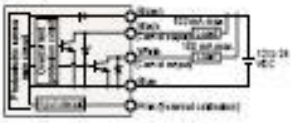


FS-T1/M1/T1G/M1H

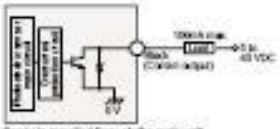


1. When the stability output is not used, cut the orange cable at the base, or connect this cable to the 0 V terminal of the power supply.
2. The FS-M1/M1H does not have a pink cable (for external calibration).

FS-V1

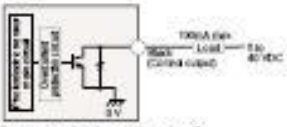


FS-V12



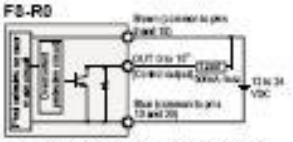
Power is supplied through the main unit.

FS-T2/M2



Power is supplied through the main unit.

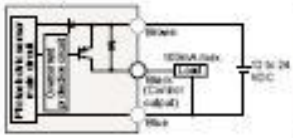
FS-R0



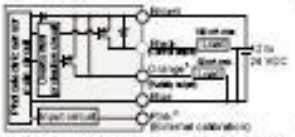
When OUT 10 is switched to STB, an over-current protection circuit is not provided.

PNP

FS-V11P

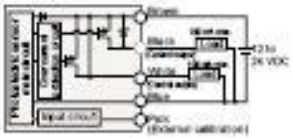


FS-T1P/M1P

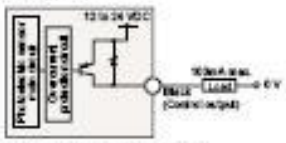


1. When the stability output is not used, cut the orange cable at the base, or connect this cable to the positive terminal of the power supply.
2. The FS-M1P does not have a pink cable.

FS-V1P

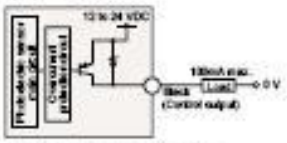


FS-V12P



Power is supplied through the main unit.

FS-T2P/M2P



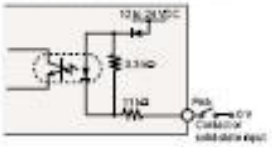
Power is supplied through the main unit.

Input circuit

NPN

FS-T1/T1G/V1

External calibration input circuit

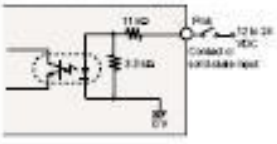


When the external calibration input is not used, cut the pink cable at the root, or connect this cable to the positive terminal of the power supply.

PNP

FS-T1P/V1P

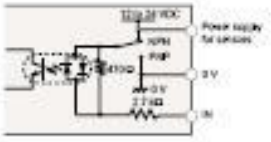
External calibration input circuit



When the external calibration input is not used, cut the pink cable at the root, or connect this cable to the 0 V terminal of the power supply.

NPN/PNP

FS-R3



Power is supplied through the main unit.

APPENDIX F

MAX 232 Datasheet

19-4323; Rev 11; 2/03

MAXIM

+5V-Powered, Multichannel RS-232 Drivers/Receivers

General Description

The MAX220–MAX249 family of line drivers/receivers is intended for all EIA/TIA-232E and V.28/V.24 communications interfaces, particularly applications where ±12V is not available.

These parts are especially useful in battery-powered systems, since their low-power shutdown mode reduces power dissipation to less than 5µW. The MAX225, MAX233, MAX235, and MAX245/MAX246/MAX247 use no external components and are recommended for applications where printed circuit board space is critical.

Applications

Portable Computers

Low-Power Modems

Interface Translation

Battery-Powered RS-232 Systems

Multidrop RS-232 Networks

Features

Superior to Bipolar

- Operate from Single +5V Power Supply (+5V and +12V—MAX231/MAX239)
- Low-Power Receive Mode in Shutdown (MAX223/MAX242)
- Meet All EIA/TIA-232E and V.28 Specifications
- Multiple Drivers and Receivers
- 3-State Driver and Receiver Outputs
- Open-Line Detection (MAX243)

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX220CPE	0°C to +70°C	16 Plastic DIP
MAX220CSE	0°C to +70°C	16 Narrow SO
MAX220CWE	0°C to +70°C	16 Wide SO
MAX220C/D	0°C to +70°C	Dice*
MAX220EPE	-40°C to +85°C	16 Plastic DIP
MAX220ESE	-40°C to +85°C	16 Narrow SO
MAX220EWE	-40°C to +85°C	16 Wide SO
MAX220EJE	-40°C to +85°C	16 CERDIP
MAX220MJE	-55°C to +125°C	16 CERDIP

Ordering Information continued at end of data sheet.

*Contact factory for dice specifications.

Selection Table

Part Number	Power Supply (V)	No. of RS-232 Drivers/Rx	No. of Ext. Caps	Nominal Cap. Value (µF)	SHDN & Three-State	Rx Active in SHDN	Data Rate (kbps)	Features
MAX220	+5	2/2	4	0.1	No	—	120	Ultra-low-power, industry-standard pinout
MAX222	+5	2/2	4	0.1	Yes	—	200	Low-power shutdown
MAX223 (MAX213)	+5	4/5	4	1.0 (0.1)	Yes	✔	120	MAX241 and receivers active in shutdown
MAX225	+5	5/5	0	—	Yes	✔	120	Available in SO
MAX230 (MAX200)	+5	5/0	4	1.0 (0.1)	Yes	—	120	5 drivers with shutdown
MAX231 (MAX201)	+5 and +7.5 to +13.2	2/2	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; same functions as MAX232
MAX232 (MAX202)	+5	2/2	4	1.0 (0.1)	No	—	120 (64)	Industry standard
MAX232A	+5	2/2	4	0.1	No	—	200	Higher slew rate, small caps
MAX233 (MAX203)	+5	2/2	0	—	No	—	120	No external caps
MAX233A	+5	2/2	0	—	No	—	200	No external caps, high slew rate
MAX234 (MAX204)	+5	4/0	4	1.0 (0.1)	No	—	120	Replaces 1488
MAX235 (MAX205)	+5	5/5	0	—	Yes	—	120	No external caps
MAX236 (MAX206)	+5	4/3	4	1.0 (0.1)	Yes	—	120	Shutdown, three state
MAX237 (MAX207)	+5	5/3	4	1.0 (0.1)	No	—	120	Complements IBM PC serial port
MAX238 (MAX208)	+5	4/4	4	1.0 (0.1)	No	—	120	Replaces 1488 and 1489
MAX239 (MAX209)	+5 and +7.5 to +13.2	3/5	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; single-package solution for IBM PC serial port
MAX240	+5	5/5	4	1.0	Yes	—	120	DIP or flatpack package
MAX241 (MAX211)	+5	4/5	4	1.0 (0.1)	Yes	—	120	Complete IBM PC serial port
MAX242	+5	2/2	4	0.1	Yes	✔	200	Separate shutdown and enable
MAX243	+5	2/2	4	0.1	No	—	200	Open-line detection simplifies cabling
MAX244	+5	8/10	4	1.0	No	—	120	High slew rate
MAX245	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, two shutdown modes
MAX246	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, three shutdown modes
MAX247	+5	8/9	0	—	Yes	✔	120	High slew rate, int. caps, nine operating modes
MAX248	+5	8/8	4	1.0	Yes	✔	120	High slew rate, selective half-chip enables
MAX249	+5	8/10	4	1.0	Yes	✔	120	Available in quad flatpack package

For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

+5V-Powered, Multichannel RS-232 Drivers/Receivers

ABSOLUTE MAXIMUM RATINGS—MAX220/222/232A/233A/242/243

Supply Voltage (V_{CC}) ..... -0.3V to +6V
Input Voltages
T_{IN} ..... -0.3V to (V_{CC} + 0.3V)
R_{IN} (Except MAX220) ..... ±30V
R_{IN} (MAX220) ..... ±25V
T_{OUT} (Except MAX220) (Note 1) ..... ±15V
T_{OUT} (MAX220) ..... ±13.2V
Output Voltages
T_{OUT} ..... ±15V
R_{OUT} ..... -0.3V to (V_{CC} + 0.3V)
Driver/Receiver Output Short Circuited to GND ..... Continuous
Continuous Power Dissipation (T_A = +70°C)
16-Pin Plastic DIP (derate 10.53mW/°C above +70°C) ... 842mW
18-Pin Plastic DIP (derate 11.11mW/°C above +70°C) ... 889mW
20-Pin Plastic DIP (derate 8.00mW/°C above +70°C) ... 440mW
16-Pin Narrow SO (derate 8.70mW/°C above +70°C) ... 696mW
16-Pin Wide SO (derate 9.52mW/°C above +70°C) ... 762mW
18-Pin Wide SO (derate 9.52mW/°C above +70°C) ... 762mW
20-Pin Wide SO (derate 10.00mW/°C above +70°C) ... 800mW
20-Pin SSOP (derate 8.00mW/°C above +70°C) ... 640mW
16-Pin CERDIP (derate 10.00mW/°C above +70°C) ... 800mW
18-Pin CERDIP (derate 10.53mW/°C above +70°C) ... 842mW
Operating Temperature Ranges
MAX2_ _AC_ _ MAX2_ _C_ _ ..... 0°C to +70°C
MAX2_ _AE_ _ MAX2_ _E_ _ ..... -40°C to +85°C
MAX2_ _AM_ _ MAX2_ _M_ _ ..... -55°C to +125°C
Storage Temperature Range ..... -65°C to +160°C
Lead Temperature (soldering, 10s) ..... +300°C

Note 1: Input voltage measured with T_{OUT} in high-impedance state, $\overline{SHDN}$ or V_{CC} = 0V.
Note 2: For the MAX220, V+ and V- can have a maximum magnitude of 7V, but their absolute difference cannot exceed 13V.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243

(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, MAX220, C1 = 0.047µF, C2–C4 = 0.33µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
RS-232 TRANSMITTERS						
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to GND		±5	±8		V
Input Logic Threshold Low				1.4	0.8	V
Input Logic Threshold High	All devices except MAX220		2	1.4		V
	MAX220: V_{CC} = 5.0V		2.4			
Logic Pull-Up/Input Current	All except MAX220, normal operation			5	40	µA
	$\overline{SHDN}$ = 0V, MAX222/242, shutdown, MAX220			±0.01	±1	
Output Leakage Current	V_{CC} = 5.5V, $\overline{SHDN}$ = 0V, V_{OUT} = ±15V, MAX222/242			±0.01	±10	µA
	V_{CC} = $\overline{SHDN}$ = 0V, V_{OUT} = ±15V			±0.01	±10	
Data Rate				200	116	kbps
Transmitter Output Resistance	V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V		300	10M		Ω
Output Short-Circuit Current	V_{OUT} = 0V		±7	±22		mA
RS-232 RECEIVERS						
RS-232 Input Voltage Operating Range					±30	V
RS-232 Input Threshold Low	V_{CC} = 5V	All except MAX243 $R2_{IN}$	0.8	1.3		V
		MAX243 $R2_{IN}$ (Note 2)	-3			
RS-232 Input Threshold High	V_{CC} = 5V	All except MAX243 $R2_{IN}$		1.8	2.4	V
		MAX243 $R2_{IN}$ (Note 2)		-0.5	-0.1	
RS-232 Input Hysteresis	All except MAX243, V_{CC} = 5V, no hysteresis in shdn.		0.2	0.5	1	V
	MAX243			1		
RS-232 Input Resistance			3	5	7	kΩ
TTL/CMOS Output Voltage Low	I_{OUT} = 3.2mA			0.2	0.4	V
TTL/CMOS Output Voltage High	I_{OUT} = -1.0mA		3.5	V_{CC} - 0.2		V
TTL/CMOS Output Short-Circuit Current	Sourcing V_{OUT} = GND		-2	-10		mA
	Sinking V_{OUT} = V_{CC}		10	30		

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243 (continued)
(V_{CC} = +5V ±10%, C1–C4 = 0.1µF, MAX220, C1 = 0.047µF, C2–C4 = 0.33µF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

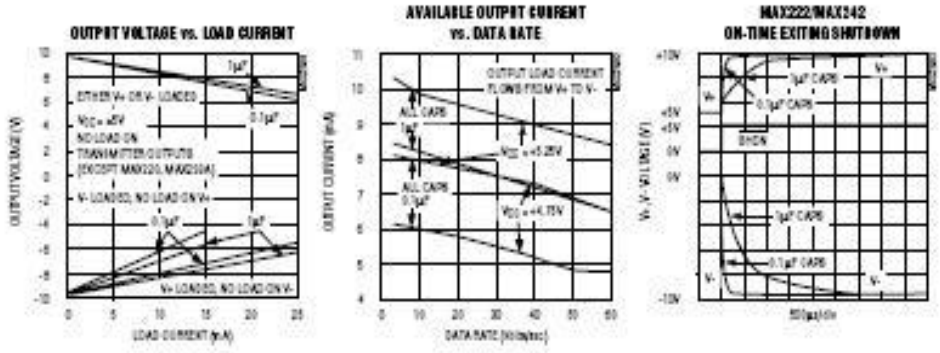
PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
TTL/CMOS Output Leakage Current	$\overline{SHDN}$ = V_{CC} or $\overline{EN}$ = V_{CC} ($\overline{SHDN}$ = 0V for MAX222), 0V ≤ V_{OUT} ≤ V_{CC}			±0.05	±10	µA
$\overline{EN}$ Input Threshold Low	MAX242			1.4	0.8	V
$\overline{EN}$ Input Threshold High	MAX242		2.0	1.4		V
Operating Supply Voltage			4.5		5.5	V
V_{CC} Supply Current ($\overline{SHDN}$ = V_{CC}), Figures 5, 6, 11, 12	No load	MAX220		0.5	2	mA
		MAX222/232A/233A/242/243		4	10	
	3kΩ load both inputs	MAX220		12		
		MAX222/232A/233A/242/243		15		
Shutdown Supply Current	MAX222/242	T_A = +25°C		0.1	10	µA
		T_A = 0°C to +70°C		2	50	
		T_A = -40°C to +85°C		2	50	
		T_A = -55°C to +125°C		35	100	
$\overline{SHDN}$ Input Leakage Current	MAX222/242				±1	µA
$\overline{SHDN}$ Threshold Low	MAX222/242			1.4	0.8	V
$\overline{SHDN}$ Threshold High	MAX222/242		2.0	1.4		V
Transition Slew Rate	C_L = 50pF to 2500pF, R_L = 3kΩ to 7kΩ, V_{CC} = 5V, T_A = +25°C, measured from +3V to -3V or -3V to +3V	MAX222/232A/233A/242/243	6	12	30	V/µs
		MAX220	1.5	3	30	
Transmitter Propagation Delay TTL to RS-232 (Normal Operation), Figure 1	t_{PHLT}	MAX222/232A/233A/242/243		1.3	3.5	µs
		MAX220		4	10	
	t_{PLHT}	MAX222/232A/233A/242/243		1.5	3.5	
		MAX220		5	10	
Receiver Propagation Delay RS-232 to TTL (Normal Operation), Figure 2	t_{PHLR}	MAX222/232A/233A/242/243		0.5	1	µs
		MAX220		0.6	3	
	t_{PLHR}	MAX222/232A/233A/242/243		0.6	1	
		MAX220		0.8	3	
Receiver Propagation Delay RS-232 to TTL (Shutdown), Figure 2	t_{PHLS}	MAX242		0.5	10	µs
	t_{PLHS}	MAX242		2.5	10	
Receiver-Output Enable Time, Figure 3	t_{ER}	MAX242		125	500	ns
Receiver-Output Disable Time, Figure 3	t_{DR}	MAX242		160	500	ns
Transmitter-Output Enable Time ($\overline{SHDN}$ Goes High), Figure 4	t_{ET}	MAX222/242, 0.1µF caps (includes charge-pump start-up)		250		µs
Transmitter-Output Disable Time ($\overline{SHDN}$ Goes Low), Figure 4	t_{DT}	MAX222/242, 0.1µF caps		600		ns
Transmitter + to - Propagation Delay Difference (Normal Operation)	t_{PHLT} - t_{PLHT}	MAX222/232A/233A/242/243		300		ns
		MAX220		2000		
Receiver + to - Propagation Delay Difference (Normal Operation)	t_{PHLR} - t_{PLHR}	MAX222/232A/233A/242/243		100		ns
		MAX220		225		

Note 3: MAX243 $R2_{OUT}$ is guaranteed to be low when $R2_{IN}$ is ≥ 0V or is floating.

+5V-Powered, Multichannel RS-232 Drivers/Receivers

Typical Operating Characteristics

MAX220/MAX222/MAX232A/MAX233A/MAX242/MAX243



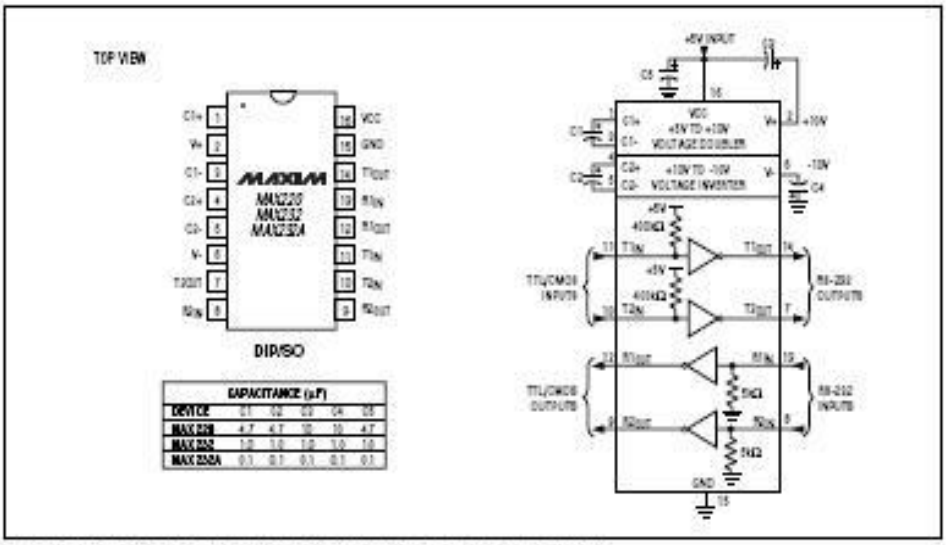


Figure 5. MAX220/MAX232/MAX232A Pin Configuration and Typical Operating Circuit

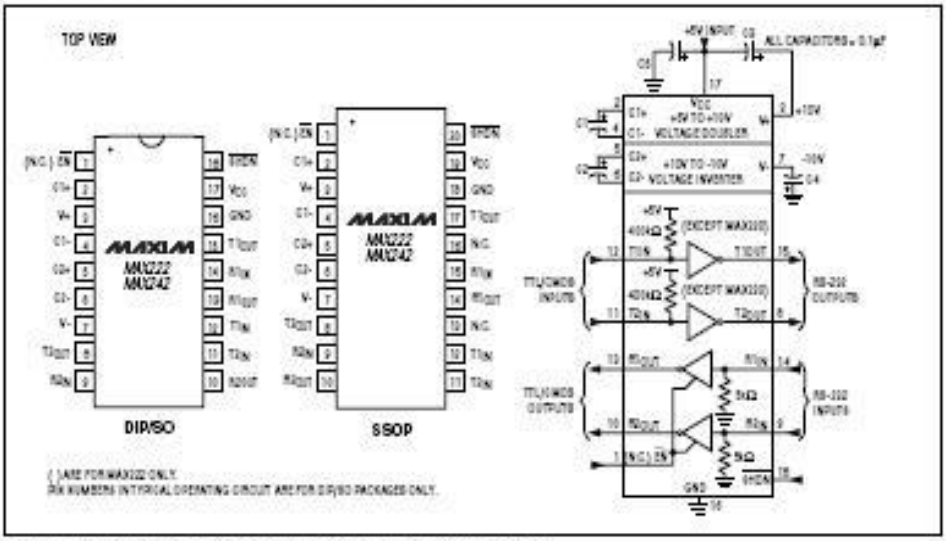


Figure 6. MAX222/MAX242 Pin Configurations and Typical Operating Circuit

APPENDIX G

Power Transistor Datasheet

OptiMOS®2 Power-Transistor

Features

- Ideal for high-frequency dc/dc converters
- N-channel
- Logic level
- Excellent gate charge x $R_{DS(on)}$ product (FOM)
- Very low on-resistance $R_{DS(on)}$
- Superior thermal resistance
- 175 °C operating temperature
- dv/dt rated

Product Summary

V_{DS}	25	V
$R_{DS(on),max}$ (SMD version)	5.9	mΩ
I_D	50	A

P-TO263-3-2 P-TO262-3-1 P-TO220-3-1

Type	Package	Ordering Code	Marking
IPB06N03LA	P-TO263-3-2	Q67042-S4145	06N03LA
IPI06N03LA	P-TO262-3-1	Q67042-S4147	06N03LA
IPP06N03LA	P-TO220-3-1	Q67042-S4148	06N03LA

Maximum ratings, at T_j=25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value	Unit
Continuous drain current	I_D	T_C=25 °C[1]	50	A
		T_C=100 °C	50	
Pulsed drain current	$I_{D,pulse}$	T_C=25 °C[2]	350	
Avalanche energy, single pulse	E_{AS}	I_D=45 A, R_{GS}=25 Ω	225	mJ
Reverse diode dv/dt	dv/dt	I_D=50 A, V_{DS}=20 V, dI/dt=200 A/µs, $T_{j,max}$=175 °C	6	kV/µs
Gate source voltage[3]	V_{GS}		±20	V
Power dissipation	P_{tot}	T_C=25 °C	83	W
Operating and storage temperature	T_j, T_{stg}		-55 ... 175	°C
IEC climatic category; DIN IEC 68-1			55/175/56	

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	
Thermal characteristics						
Thermal resistance, junction - case	R_{thJC}		-	-	1.8	K/W
SMD version, device on PCB	R_{thJA}	minimal footprint	-	-	62	
		6 cm² cooling area[4]	-	-	40	
Electrical characteristics, at T_j=25 °C, unless otherwise specified						
Static characteristics						
Drain-source breakdown voltage	$V_{(BR)DSS}$	V_{GS}=0 V, I_D=1 mA	25	-	-	V
Gate threshold voltage	$V_{GS(th)}$	V_{DS}=V_{GS}, I_D=40 µA	1.2	1.6	2	
Zero gate voltage drain current	I_{DSS}	V_{DS}=25 V, V_{GS}=0 V, T_j=25 °C	-	0.1	1	µA
		V_{DS}=25 V, V_{GS}=0 V, T_j=125 °C	-	10	100	
Gate-source leakage current	I_{GSS}	V_{GS}=20 V, V_{DS}=0 V	-	10	100	nA
Drain-source on-state resistance	$R_{DS(on)}$	V_{GS}=4.5 V, I_D=30 A	-	7.9	9.9	mΩ
		V_{GS}=4.5 V, I_D=30 A, SMD version	-	7.6	9.5	
		V_{GS}=10 V, I_D=30 A	-	5.2	6.2	
		V_{GS}=10 V, I_D=30 A, SMD version	-	4.9	5.9	
Gate resistance	R_G		-	1.2	-	Ω
Transconductance	g_{fs}	$\|V_{DS}\|>2\|I_D\|R_{DS(on)max}$, I_D=30 A	26	52	-	S

[1] Current is limited by bondwire; with an R_{thJC}=1.8 K/W the chip is able to carry 91 A.

[2] See figure 3

[3] $T_{j,max}$=150 °C and duty cycle D=0.25 for V_{GS}<-5 V

[4] Device on 40 mm x 40 mm x 1.5 mm epoxy PCB FR4 with 6 cm² (one layer, 70 µm thick) copper area for drain connection. PCB is vertical in still air.

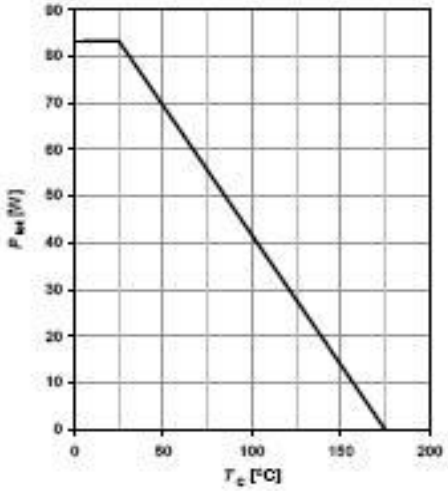
Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	
Dynamic characteristics						
Input capacitance	C_{iss}	V_{GS}=0 V, V_{DS}=15 V, f=1 MHz	-	1995	2653	pF
Output capacitance	C_{oss}		-	848	1128	
Reverse transfer capacitance	C_{rss}		-	124	186	
Turn-on delay time	$t_{d(on)}$	V_{DD}=15 V, V_{GS}=10 V, I_D=25 A, R_G=2.7 Ω	-	11	16	ns
Rise time	t_r		-	25	38	
Turn-off delay time	$t_{d(off)}$		-	30	45	
Fall time	t_f		-	7.0	10	
Gate Charge Characteristics[5]						
Gate to source charge	Q_{gs}	V_{DD}=15 V, I_D=25 A, V_{GS}=0 to 5 V	-	7	9	nC
Gate charge at threshold	$Q_{g(th)}$		-	3.2	4.2	
Gate to drain charge	Q_{gd}		-	5	7	
Switching charge	Q_{sw}		-	8	12	
Gate charge total	Q_g		-	16	22	
Gate plateau voltage	$V_{plateau}$		-	3.3	-	V
Gate charge total, sync. FET	$Q_{g(sync)}$	V_{DS}=0.1 V, V_{GS}=0 to 5 V	-	14	19	nC
Output charge	Q_{oss}	V_{DD}=15 V, V_{GS}=0 V	-	18	22	
Reverse Diode						
Diode continous forward current	I_S	T_C=25 °C	-	-	50	A
Diode pulse current	$I_{S,pulse}$		-	-	350	
Diode forward voltage	V_{SD}	V_{GS}=0 V, I_F=50 A, T_j=25 °C	-	0.94	1.2	V
Reverse recovery charge	Q_{rr}	V_R=15 V, I_F=I_S, dI_F/dt=400 A/µs	-	-	10	nC

[5] See figure 16 for gate charge parameter definition

Next Page

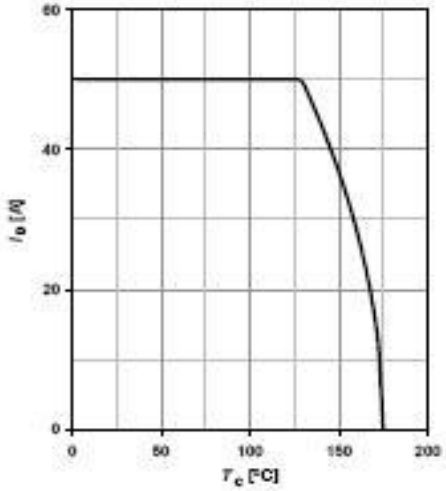
1 Power dissipation

$P_{tot}=f(T_C)$



2 Drain current

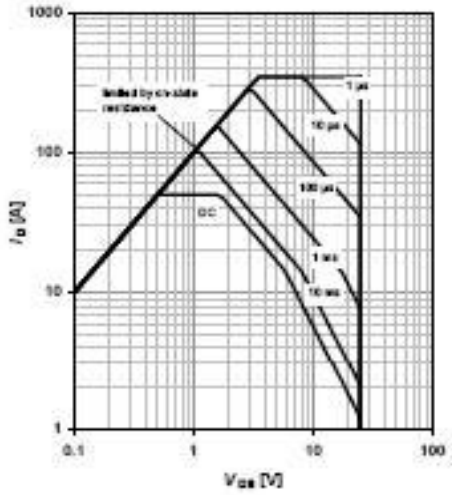
$I_D=f(T_C)$; $V_{GS}\geq 10$ V



3 Safe operation area

$I_D=f(V_{DS})$; $T_C=25$ °C; $D=0$

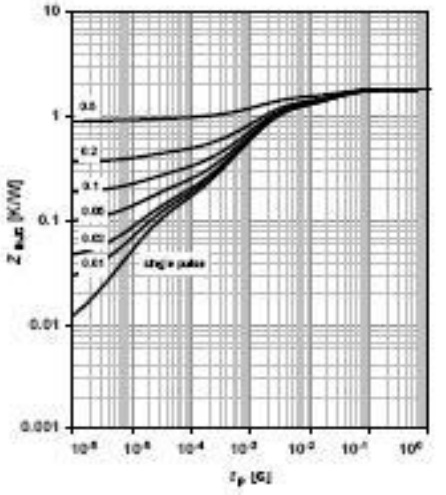
parameter: t_p



4 Max. transient thermal impedance

$Z_{thJC}=f(t_p)$

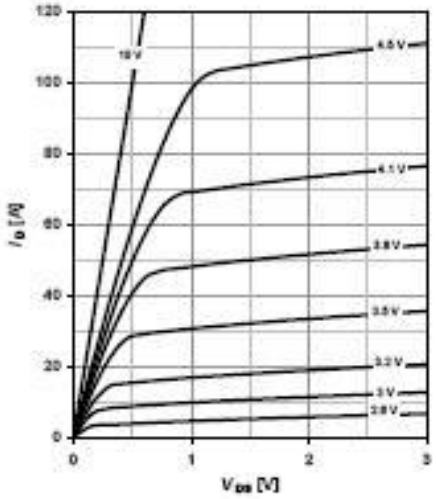
parameter: $D=t_p/T$



5 Typ. output characteristics

$I_D=f(V_{DS})$; $T_j=25$ °C

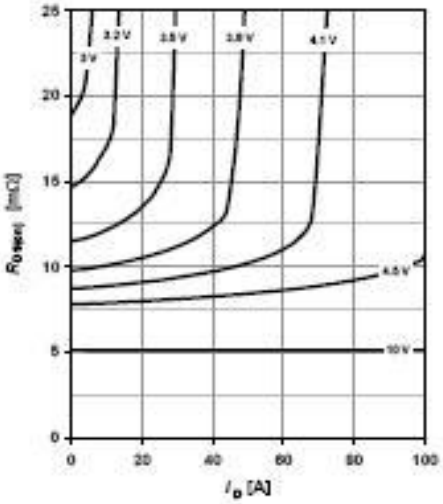
parameter: V_{GS}



6 Typ. drain-source on resistance

$R_{DS(on)}=f(I_D)$; $T_j=25$ °C

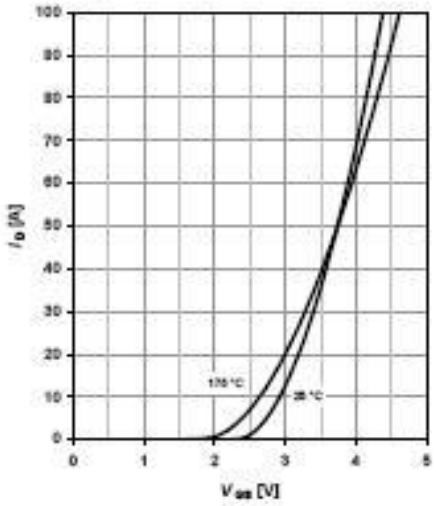
parameter: V_{GS}



7 Typ. transfer characteristics

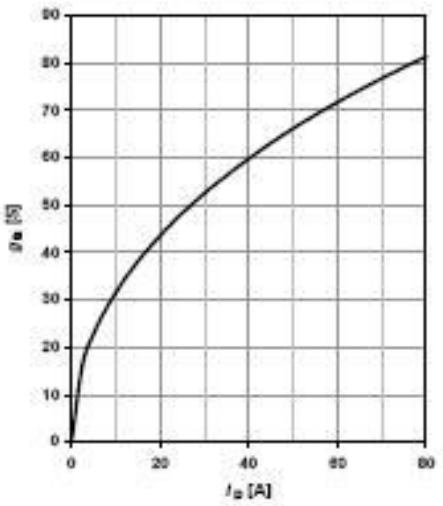
$I_D=f(V_{GS})$; $|V_{DS}|>2|I_D|R_{DS(on)max}$

parameter: T_j



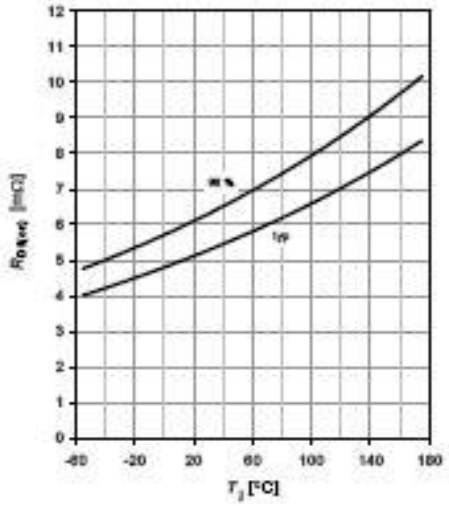
8 Typ. forward transconductance

$g_{fs}=f(I_D)$; $T_j=25$ °C



9 Drain-source on-state resistance

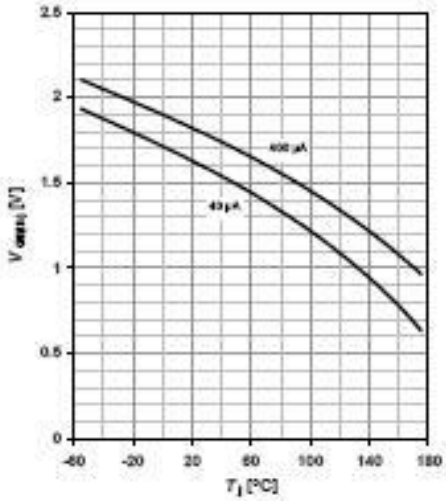
$R_{DS(on)}=f(T_j)$; I_D=30 A; V_{GS}=10 V



10 Typ. gate threshold voltage

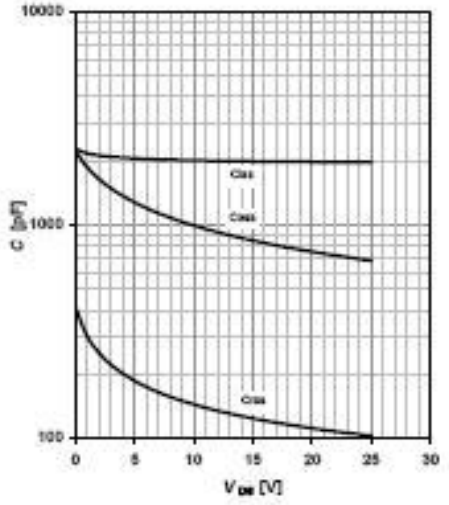
$V_{GS(th)}=f(T_j)$; $V_{GS}=V_{DS}$

parameter: I_D



11 Typ. Capacitances

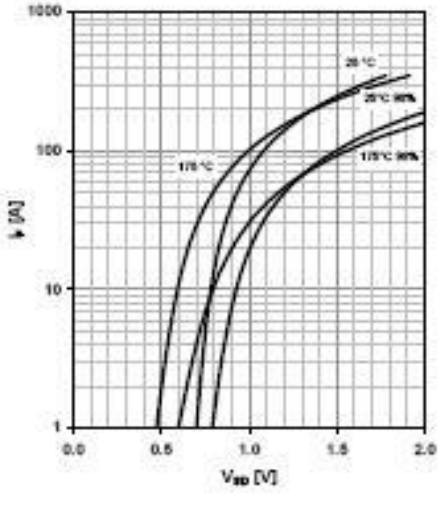
$C=f(V_{DS})$; V_{GS}=0 V; f=1 MHz



12 Forward characteristics of reverse diode

$I_F=f(V_{SD})$

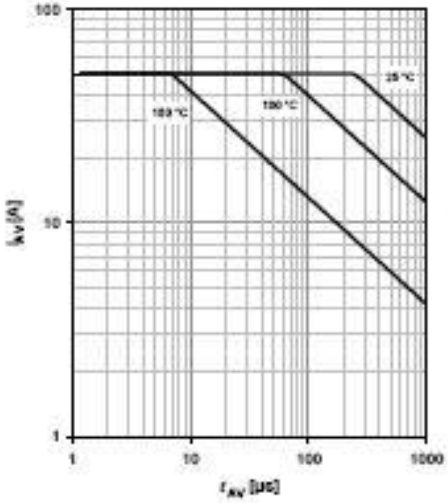
parameter: T_j



13 Avalanche characteristics

$I_{AS}=f(t_{AV})$; $R_{GS}=25\ \Omega$

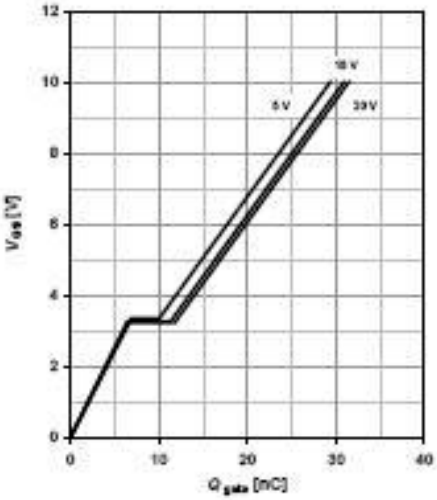
parameter: $T_{j(start)}$



14 Typ. gate charge

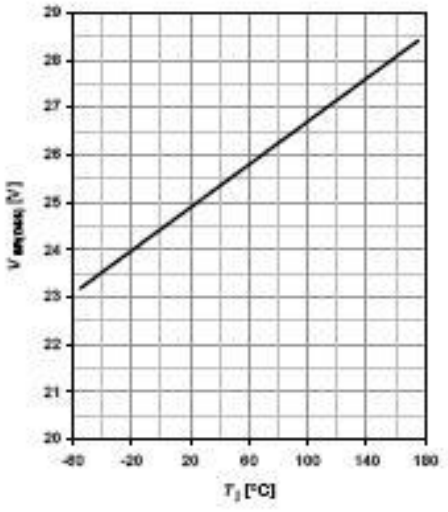
$V_{GS}=f(Q_{gate})$; $I_D=25$ A pulsed

parameter: V_{DD}

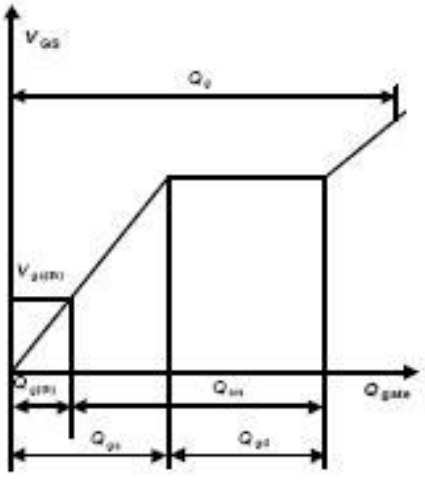


15 Drain-source breakdown voltage

$V_{BR(DSS)}=f(T_j)$; $I_D=1$ mA

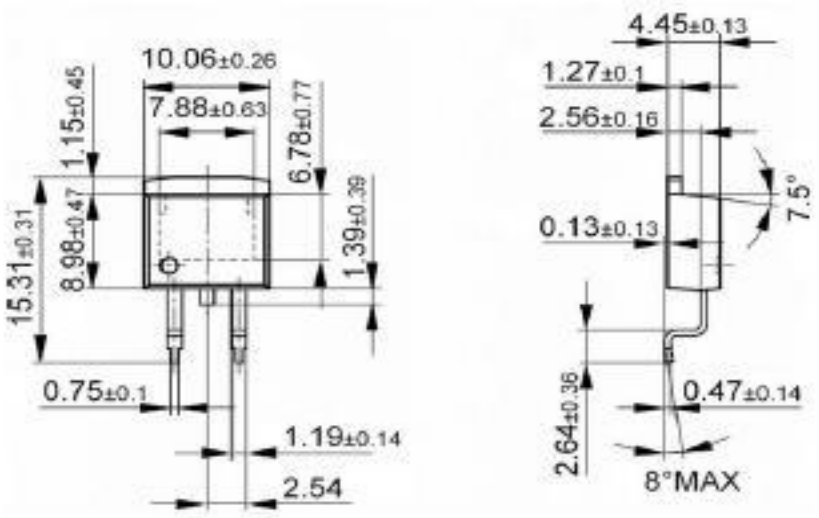


16 Gate charge waveforms

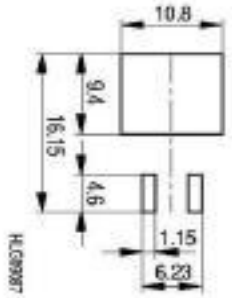


Package Outline

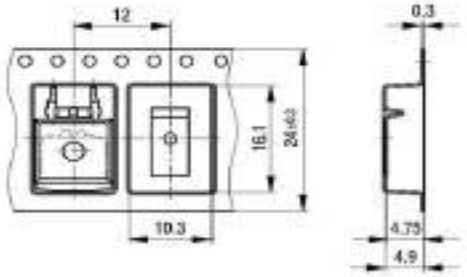
P-TO263-3-2: Outline



Footprint

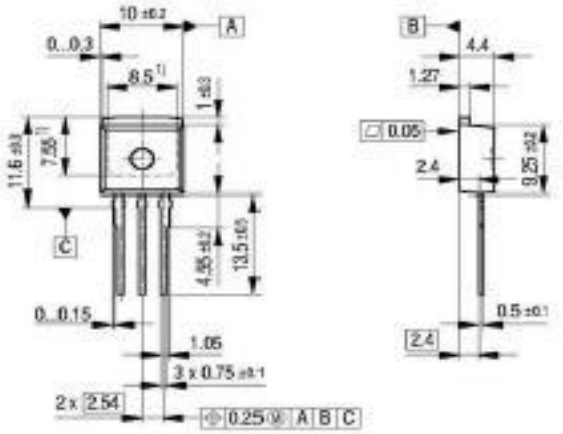


Packaging



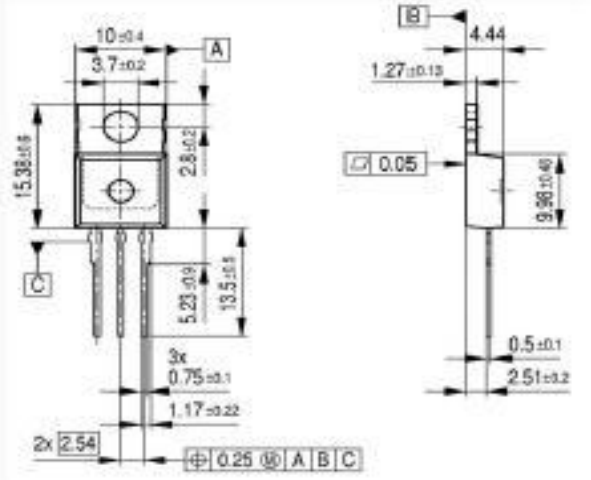
Dimensions in mm

P-TO262-3-1: Outline



1) Typical
Metal surface min. X = 7.25, Y = 6.9
All metal surfaces tin plated, except area of cut.

P-TO220-3-1: Outline



All metal surfaces tin plated, except area of cut.
Metal surface min. x=7.25, y=12.3

Dimensions in mm

Packaging

APPENDIX H

LM7805 Voltage Regulator Datasheet

FAIRCHILD
SEMICONDUCTOR®

April 1999
Revised December 2005

LM7805 • LM7806 • LM7808 • LM7809 • LM7810 • LM7812 • LM7815 • LM7818 • LM7824 • LM7805A • LM7806A • LM7808A •LM7809A • LM7810A • LM7812A • LM7815A • LM7818A • LM7824A

3-Terminal 1A Positive Voltage Regulator

General Description

The LM78XX series of three terminal positive regulators are available in the TO-220 package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 12, 15, 18, 24
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Ordering Code:

Product Number	Output Voltage Tolerance	Package	Operating Temperature
LM7805CT	±4%	TO-220	-40°C - +125°C
LM7806CT			
LM7808CT			
LM7809CT			
LM7810CT			
LM7812CT			
LM7815CT			
LM7818CT			
LM7824CT			
LM7805ACT	±2%		0°C - +125°C
LM7806ACT			
LM7808ACT			
LM7809ACT			
LM7810ACT			
LM7812ACT			
LM7815ACT			
LM7818ACT			
LM7824ACT			

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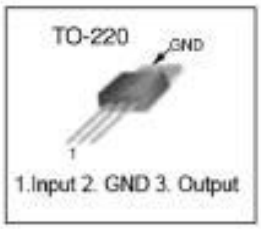
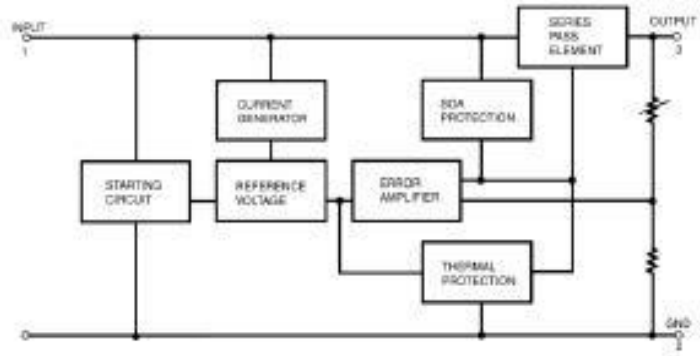


Internal Block Diagram



Absolute Maximum Ratings(Note 1)

Parameter	Symbol	Value	Unit
Input Voltage (for V_O = 5V to 18V)	V_I	35	V
(for V_O = 24V)	V_I	40	V
Thermal Resistance Junction-Cases (TO-220)	$R_{\theta JC}$	5	°C/W
Thermal Resistance Junction-Air (TO-220)	$R_{\theta JA}$	65	°C/W
Operating Temperature Range	T_{OPR}	0 ~ +125	°C
LM78xx		−40 ~ +125	°C
LM78xxA		0 ~ +125	°C
Storage Temperature Range	T_{STG}	−65 ~ +150	°C

Note 1: Absolute maximum ratings are those values beyond which damage to the device may occur. The datasheet specifications should be met, without exception, to ensure that the system design is reliable over its power supply, temperature, and output/input loading variables. Fairchild does not recommend operation outside datasheet specifications.

Electrical Characteristics (LM7805)

(Refer to the test circuits, −40°C < T_J < 125°C, I_O = 500mA, V_I = 10V, C_I = 0.1μF, unless otherwise specified)

Parameter	Symbol	Conditions		Min	Typ	Max	Unit
Output Voltage	V_O	T_J = +25°C		4.8	5.0	5.2	V
		5mA ≤ I_O ≤ 1A, P_D ≤ 15W, V_I = 7V to 20V		4.75	5.0	5.25	V
Line Regulation	Regline	T_J = +25°C	V_O = 7V to 25V	–	4.0	100	mV
(Note 2)			V_I = 8V to 12V	–	1.6	50.0	mV
Load Regulation	Regload	T_J = +25°C	I_O = 5mA to 1.5mA	–	9.0	100	mV
			I_O = 250mA to 750mA	–	4.0	50.0	mV
Quiescent Current	I_Q	T_J = +25°C		–	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A		–	0.03	0.5	mA
		V_I = 7V to 25V		–	0.3	1.3	mA
Output Voltage Drift (Note 3)	$\Delta V_O/\Delta T$	I_O = 5mA		–	-0.8	–	mV/°C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A = +25°C		–	42.0	–	μV/V_O
Ripple Rejection (Note 3)	RR	f = 120Hz, V_O = 8V to 18V		62.0	73.0	–	dB
Dropout Voltage	V_{DROP}	I_O = 1A, T_J = +25°C		–	2.0	–	V
Output Resistance (Note 3)	r_O	f = 1KHz		–	15.0	–	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A = +25°C		–	230	–	mA
Peak Current (Note 3)	I_{PK}	T_J = +25°C		–	2.2	–	A

Note 2: Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Note 3: These parameters, although guaranteed, are not 100% tested in production.

APPENDIX I

Using PIC16F84A Microcontroller in Intelligent Stepper Motor Control

Using the PIC16F84 Microcontroller in Intelligent Stepper Motor Control

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Abstract – For applications requiring critical rotor positioning, usually stepper motors are the best choice. Stepper motors operate differently from other motors; rather than voltage being applied and the rotor spinning smoothly, stepper motors turn on a series of electrical pulses to the motor's windings. Each pulse rotates the rotor by an exact degree and a series of pulses must be generated to perform a complete rotation. An intelligent controlling device was conceived and built based on a PIC16F84 microcontroller and UFDC-1 interface.

Keywords: stepper motor, driver, microcontroller

I. PIC16F84 MICROCONTROLLER

Suitable for various digital applications, the PIC16F84 RISC microcontroller has 13 I/O port lines, 1K Flash program memory, EEPROM data memory and an 8 bit timer/counter. The pin diagram of PIC16F84 is shown in figure 1.

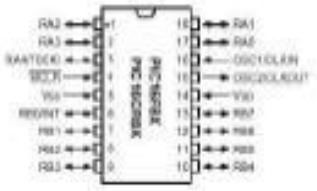

Fig. 1 PIC16F84 pin diagram

At a clock rate of 4 MHz, which is obtained by connecting a crystal oscillator between OSC1 and OSC2 pins, one instruction cycle is accomplished in 1 μs – a satisfactory speed for our application. The built in power on reset circuitry provides a safe start-up, therefore the Master Clear pin (/MCLR) is tied to VDD. Port A (RA0 – RA4) provides 5 bi-directional I/O lines and Port B (RB0 – RB7) 8 bi-directional I/O lines, independently configurable. Each line can source up to 20 mA current.

The PIC16FXX family has special features to reduce external components, thus reducing cost, enhancing system reliability and reducing power consumption. The SLEEP (power-down) mode offers power saving. The user can wake the chip from sleep through several external and internal interrupts and resets. A highly reliable Watchdog Timer with its own on-chip RC oscillator provides protection against software lock-up.

The devices with Flash program memory allow the same device package to be used for prototyping and production. In-circuit reprogrammability allows the code to be updated without the device being removed from the end application. This is useful in the development of many applications where the device may not be easily accessible, but the prototypes may require code updates. This is also useful for remote applications where the code may need to be updated [1].

In-circuit reprogrammability can be achieved using I/O pins RB6 (serial clock) and RB7 (serial data). Programming voltage (Vpp) is applied through /MCLR pin and it's value is 13.8 V. To develop application software and to program the PIC16F84 microcontroller, an original user interface was designed, including a source code editor, a compiler (Parallax Compiler) and an unique featured program mode interface which can send to the device program code, data memory code and configuration information.

A. I/O lines initialization

At start-up, each port must be initialized i.e. control bytes must be written in registers TRIS A and TRIS B which gives the I/O direction of each port line. A '1' written in TRIS x will designate the corresponding Rx line as input, while a '0' will make it an output. For example, the following sequence will make lines RA3 – RA0 inputs, RA4 – output, all RB lines output.

```
clrf    PORTA
clrf    PORTB
bsf     STATUS, RP0
```

```
movlw   0x0F
movwf   TRISA
movlw   0x00
movwf   TRISB
```

To send a byte to PORTB lines (8 bit) a mov sequence must be issued, like follows:

```
movlw   0x0FF
movwf   PORTB
```

By this, all PORTB lines are set to '1', i.e. '11111111'. PORTA being only 5 bit wide, bits 7-5 are ignored, regardless of the value written in TRISA or PORTA registers. To read a port value (a full byte) we can use the sequence:

```
mov     PORTA, 0
```

which writes the 5 bit word of PORTA into the working register W. For testing a single bit of a port line, a BTFSS or BTFSC instruction must be used. BTFSS tests the corresponding bit and if it's value is '1' skips the following instruction. If BTFSC is used, then the next instruction is skipped if the bit is '0'. This technique is useful to make conditional branches in scanning external switch states.

II. ULN 2003 POWER DRIVER

In order to control a stepper motor, the coils of each phase must be driven by a certain pulse signal which is generated by the PIC16F84 microcontroller. Since I/O lines do not source a sufficient current, an integrated power driver is used. We choose a simple, low-cost device, ULN 2003, including seven darlington arrays with TTL or CMOS compatible inputs. Each channel is rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout [2].
Figure 2 shows the pin connection of ULN 2003.

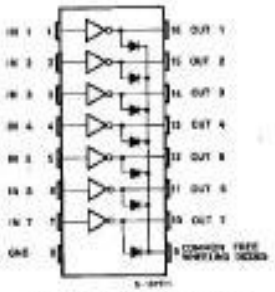

Fig. 2 ULN 2003 pin diagram

Each driver has a input, a common pin and an output as shown in figure 3.

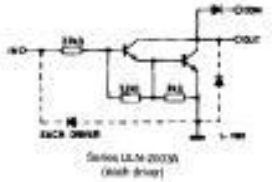

Fig.3 Internal driver schematic.

The device is powered by the external voltage supply which also driven the stepper motor's coils.

III. THE UNIVERSAL FREQUENCY-TO-DIGITAL CONVERTER (UFDC-1)

The Universal Frequency-to-Digital Converter (UFDC-1) is a universal 2-channel high precision multifunctional converter based on novel frequency-time conversion methods. It is perfectly suited to any applications where frequency-time parameters but also other sensors output signals have to be measured and transmitted to a central processing unit as a feedback in various automation systems [3].

Figure 4 shows the pin configuration of PDIP package for the UFDC-1 and Table 1 pin functionality.

Fig 4 UFDC-1 pin configuration.

Name	Pin Description
VDD	Supply voltage
GND	Ground
CH1, CT1	Input channel 1
CH2, CT2	Input channel 2
SCK/P_SCK	Bus Clock
SDI/P_SDI	Bus selection input data in
SDO, S0	Accuracy selection (see table 3)
S1, S2	Address bit for I2C bus communication
RESET	Reset input
SCK/A	SPI Bus Master: clock output
SDI/A	SPI Bus Master: data in/Slave Output
SDO/A	SPI Bus Master: Output/Slave input
SS	SPI Bus Master: Slave select
SCL	I2C bus: I2C clock/SPI bus: clock input
SDA	I2C bus: I2C data/SPI bus: data input/output
RDY	Data ready output
TEST	Test input

Table 1. Pin description

This device offers high performance with flexibility and requires minimum possible number of external components. It can be easily included into digital

environment controlled by an external microcontroller with software configured function selection.

IV. STEPPER MOTOR

The application hereby considers an unipolar stepper motor, which has logically two windings per phase, one for each direction of current. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple for each winding. A typical winding configuration is illustrated in figure 5.

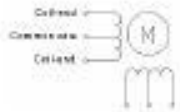

Fig. 5 Unipolar stepper motor windings

Stepper motor performance is strongly dependent on the drive circuit. Therefore we approach the latest chopper drive circuit method [4] building a digital intelligent controlling device which implements linear constant current control in combination with a pulse width modulation scheme.

V. CONTROL METHOD AND EXPERIMETAL DEVICE

We use a common unipolar stepper motor named KP4M4-001 which has four phases and 100 steps, each step being 3.6°. It has 5 terminals as shown in figure 6.

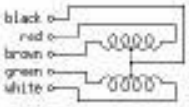

Fig. 6 KP4M4-001 motor terminals

The black terminal is common and will be connected to a 12V power supply.

Linear constant current control in combination with a pulse-width modulation scheme (chopper circuit) reduces the effect of motor winding's time constant (L/R) upon current increase during each input pulse and also cuts power dissipation too.

A four-phase unipolar stepper motor (as shown in figure 6) could use a Darlington like the ULN 2003 as a driver and a current sensing circuitry built with operational amplifiers which output in the end a frequency signal proportional with the measured winding current. This signal is fed into the UFDC-1 interface which communicates with the P8C16F84 microcontroller via the I2C protocol.

The classical topology for winding current sensing in a chopper circuit is illustrated in figure 7.

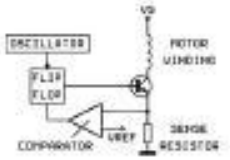

Fig. 7 Classic driver circuit with current sensing.

Our method will replace the whole sensing circuitry with a current-frequency converter connected to the UFDC-1 and controlled by the P8C16F84 microcontroller.

A. Current-frequency converter

Using operational amplifiers is an efficient and common method for such circuits. The sensing resistor will provide an input voltage for the first stage which is an integrating circuit. The resulting signal is fed to a comparator, resulting the output frequency signal. Since the UFDC-1 accepts only TTL input levels a signal conditioning circuit is required. It may be a simple transistor interface. Figure 8 shows the current-frequency converter.

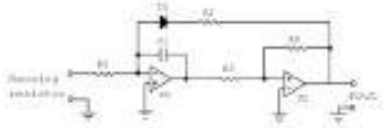

Fig. 8 Current to frequency converter.

First stage output voltage will be:

$$v_1 = -\frac{U_{in}}{R_1 C} t \qquad (1)$$

and generated output signal:

$$v_2 = \frac{U_{in}}{R_1 C} \frac{R_4}{R_3} t \qquad (2)$$

where Uin is the voltage on the sensing resistor, fed to the input of first operational amplifier (U1).
Regarding (1) and (2) and considering V11 and V12 the positive and negative saturation voltages of the comparator (U2) we have the expression of the frequency signal:

$$f = \frac{U_{in}}{R_1 C} \frac{R_4}{R_3 (V_{11} - V_{12})} \qquad (3)$$

Thus we obtain a linear dependence of the frequency f and input signal's voltage Uin also proportional with the winding's current.

Since the stepper motor has four terminals for the windings, we can use an analog CMOS multiplexer to fed the sensed voltages into the converter shown in figure 8. The TTL interface will provide the rectangular pulses for the UFDC-1's input.

The block diagram of the experimental device is shown in figure 9.

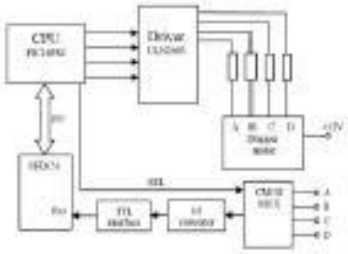

Fig. 9 Bloc diagram of control unit

Control signals for the four phase inputs are provided by the P8C16F84 microcontroller, based upon a specific algorithm. The sequence can be stored into the PIC's internal flash memory or can be read from an external I2C memory device connected on the same bus as the UFDC-1. The chopping algorithm is also provided by the microcontroller's software based upon readings from the current sensing circuit and translated by the UFDC-1. The CMOS multiplexer provides sequentially to the I/f converter the signals from the four motor windings terminals. The CPU (Central Processing Unit) triggers the multiplexer accordingly to assure the right value to be read.

VI. CONCLUSIONS

An intelligent controlling device was conceived and built based on a P8C16F84 microcontroller and UFDC-1 interface. Considering classic linear constant current control it was designed a digital sensing system for the winding's current, using current to frequency conversion and a powerful interface like UFDC-1. The Central Processing Unit is capable of rendering and processing all the tasks needed to perform a control using pulse width modulation scheme (chopping method), thus providing a simple and flexible device for stepper motor control applications.

REFERENCES

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[2] ***, ULN2003 Data sheet.
[3] IFSA, UFDC-1 Specification and Application Note.
[4] ST, Stepper-motor performance constant-current chopper drive.
[5] Popescu P., Bălăşă M., Popovici A., Arman A., Lie I., "Signal Generating Techniques using P8C16F84 Microcontroller", ICMCS-05, Proceedings of the 4'th International Conference on Microelectronics and Computer Science 15-17 September 2005, Technical University of Moldova & Academy of Sciences of Moldova, Chişinău, Vol.II, ISBN 9975-66-360-1, pg.401-404.
[6] Popescu P., Popescu V., Bălăşă M., Filip A., "Using the PIC16F84 Microcontroller in Signal Generating Techniques", EMES 2005, Proceedings of the 5'th International Conference on Engineering of Modern Electric Systems, 26-28 May, 2005, Analele Universităţii din Oradea, Fascicola Electrotehnică, Suciuman Electronică, ISBN 1454-9220, pg.25-28.

APPENDIX J

User's Manual

User's Manual

1. Place the automatic ring sizer in its desired location.
2. Plug the device in a 220 VAC.
3. Turn on the switch.
4. Open the ring calibration and finger diameter measurement system 1.0.
5. The user must enter a username and password to access the system.
6. If procedures are done, the user can choose to exit the program by clicking the logout button.

Data Management Menu (Customers)

1. Select the data management from the menu and click customers. From the customer data maintenance window, choose the desired operation to create a new entry, select 'add' entry. To edit existing profile, select 'modify' entry. To remove an entry from the database, select delete.
2. To close the current window, select exit.

To Add Entry

a. Click 'add entry' button.
b. All fields must be filled up with necessary information, including the finger sizes before saving the profile. (See Measurement Procedures)
c. Click 'save' to update the system.
d. To cancel the process, click the 'cancel' button.

To Modify Entry

- Select the customer's profile to be modified.
- Click 'modify entry' button.
- Select the field to be edited.
- Click 'save' to update the system.
- To cancel the process, click the 'cancel' button.

To Delete Entry

- Select the customer's profile to be deleted.
- Click 'delete' entry button.
- The customer's profile window will be seen, then click 'delete' to remove the entry from the system.
- To cancel the process, click the 'cancel' button.

Data Management Menu (Rings)

1. Select the data management from the menu and click 'Rings'. This window modifies the properties of every ring in the system.
2. Select the ring to be modified then click modify existing button.
3. Choose field to be edited and click 'save' to update the system.
4. To cancel the process, click the 'cancel' button.

Data Management Menu (Users)

1. Select the data management from the menu and click users. This window creates an account for the users for log in process.
2. From this window, choose the desired operation, to create a new account, select 'add' entry. To edit existing account, select 'modify' entry. To remove an account from the database, select 'delete'.
3. To close the current window, select 'exit'.

To Add Account

a. Click 'add' new button.
b. Enter username and password. Both fields can be alphanumeric.
c. Clicks 'save' to update the system.
d. To cancel the process, click the 'cancel' button.

To Modify Account

- Select the user's account to be modified.
- Click 'modify existing' button.
- Select the field to be edited.
- Click 'save' to update the system.
- To cancel the process, click the 'cancel' button.

To Delete Account

- Select the user's account to be deleted.
- Click 'delete' button.
- The customer's profile window will be seen then click 'delete' to remove the entry from the system.
- To cancel the process, click the 'cancel' button.

Transactions

1. Click the customer name field. A new window will be seen which shows the list of customers stored in the system.
2. Select the name of the customer, then choose the selected finger from the drop down menu. This will check the ring's availability in the system.
3. The selected ring will display an image.
4. Click 'close' to exit the window.

Measurement Procedures

1. Make sure that the device is switched on and the data management window is opened simultaneously.
2. Select the finger to be measured. A new window will prompt the user to press the reset button from the device. The user must wait for the device to be fully stopped.
3. The system will prompt the user to insert the finger in the measurer. The finger must be inserted properly for accurate measurements.
4. Click 'ok' from the system to start measuring.
5. When the device stops, the user's ring size will now be displayed on the computer.
6. Repeat step 2 until all fingers are measured.

Troubleshooting Procedures

1. No power
    a. Make sure that the plug is connected to the power outlet.
    b. Check the power switch if it is turned on.
2. The device does not respond to the computer.
    a. Make sure that the serial data cable is connected in the device and to the computer.

APPENDIX K

List of Materials and Cost

List of Materials and Cost

Quantity	Description	Price per unit	Total
2 pcs	Fiber Optic Proximity Sensor Head	Php150.00	Php300.00
2 pcs	Fiber Optic Proximity Sensor Amplifier	Php500.00	Php1000.00
1 pc	Unipolar Stepper Motor	Php350.00	Php350.00
1 pc	Max232 IC	Php45.00	Php45.00
3 pcs	Monolithic Capacitor 0.1µF	Php2.50	Php7.00
1 pc	DB-9 Cable Connector	Php25.00	Php25.00
1 pc	DB-9 Port	Php19.00	Php19.00
1 pc	PIC16F84A Microcontroller	Php150.00	Php150.00
6 pcs	Resistors 22KΩ	Php1.00	Php6.00
4 pcs	Resistors 400Ω	Php1.00	Php4.00
1 pc	Crystal Oscillator 4MHz	Php20.00	Php20.00
2 pcs	Electrolytic Capacitor 33pF	Php2.00	Php4.00
1 pc	Electrolytic Capacitor 0.1µF	Php2.50	Php2.50
4 pcs	MOSFET03N06	Php35.00	Php140.00
4 pcs	Diode1N4006	Php2.50	Php10.00
1 pc	Switching Mode Power Supply	Php750.00	Php750.00
1 pc	7805 Voltage Regulator	Php30.00	Php30.00
1 pc	Electrolytic Capacitor 4700µF	Php35.00	Php35.00
1 pc	Electrolytic Capacitor 1000µF	Php10.00	Php10.00
2 pcs	Push Buttons	Php20.00	Php40.00
1 pc	Power Switch	Php20.00	Php20.00
1 pc	Power Plug	Php50.00	Php50.00
1 pc	Casing	Php120.00	Php120.00
	Total Price		Php3137.50